Pesticide Discharge Management Plan (PDMP)

Pesticide Discharge Management Plan

LAKE AUBURN

Lake Auburn Watershed Protection Commission

Auburn Water District
P.O. Box 414
268 Court St.
Auburn, Maine 04210

Lewiston Water Division
103 Adams Ave.
Lewiston, Maine 04240

PDMP Preparation Date:
March 2013

Table of Contents

SECTION 1: Operator Information

Lake Auburn has a 135 year history of being the drinking water supply for the Cities of Lewiston and Auburn, Maine (population 60,000). The Lake covers approximately 3-1/2 square miles, with a maximum depth of 120'. In addition to being the sole drinking water supply for the Cities, Lake Auburn is a well renowned cold water fishery, and supports Landlocked Salmon, Brook Trout, Lake Trout, as well as warm water species. Historically, the quality of the raw Lake water has been excellent as a result of a strong watershed protection program implemented by the two communities through the Lake Auburn Watershed Protection Commission (LAWPC).

Lake Auburn is a surface water supply, and the raw water is not filtered. LWD/AWD received a waiver of filtration in 1993 from the Environmental Protection Agency (EPA). It was at this time that the LAWPC was formed.

In 2011, and again in 2012 the Lake experienced algae blooms. The bloom in 2012 depleted the oxygen level to the point that some of the Lake Trout did not survive. From a drinking water stand point, the greatest threat of algae in the water is the effect on turbidity, which cannot exceed 5NTU. We have never exceeded that threshold, and want to stay below that limit in order to avoid a boil water notice or loss of the waiver.

In the Fall of 2102 LWD/AWD assembled a stakeholders group, and hired consultants CDM/Smith, and CEI Inc. to investigate the issue, and make recommendations to bring the Lake back to health. Phase I of the investigation includes data collection and analysis, and Phase II will include short and long term recommendations for remediation.

At this time, Phase I has been completed. While relationships between drivers of decreased water quality are not completely known, it is clear that if the quality in the lake continues to degrade construction of more advanced water treatment facilities may be required. Short term recommendations for remediation include the application of an algaecide in the Spring/Summer/Fall of 2013. The application of an algaecide would be designed to limit algae growth before a bloom occurs, and afford us some time to address the long term goal of limiting phosphorus contributions from the watershed.

The Lake will be closely monitored in 2013. We are hopeful that an algaecide treatment will not be necessary; however, we are planning to have a permit in hand, and an applicator on board for rapid deployment if needed.

SECTION 2: PDMP Team

The development of a PDMP requires the establishment of a PDMP Team. The team shall be comprised of the following members and assigned responsibilities:

A. **Person(s) responsible for managing pests in relation to the pest management area.**

Lake Auburn Watershed Protection Commission (LAWPC)

Through the Auburn Water District (AWD), and Lewiston Water Division (LWD), the LAWPC will approve and fund the treatment processes that are ultimately undertaken as identified in the PDMP.

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Lynne Richard
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Key personnel that represent AWD/LWD include:

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Mary Jane Dillingham
Water Quality Manager

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B. **Person(s) responsible for developing and revising the PDMP**

Kenneth J. Wagner, Ph.D.
Certified Lake Manager
Water Resources Services LLC
144 Crane Hill Road
Wilbraham, MA. 01095-1815
kjwagner@charter.net
(413)-219-8071

Dan Bisson, P.E.
Principle/Client Svc. Mgr.
CDM/Smith
50 Hampshire St. Cambridge, MA. 02139
BissonDP@cdmsmith.com
(207)-232-6071

Dr. Kenneth Wagner from WRS LLC, and Dan Bisson from CDM/Smith will provide the bulk of the technical information to be included in the PDMP, including problem identification, action threshold(s), an alternatives analysis, and recommended treatment including chemical identification, application method, and doses. Dr. Wagner will also provide information to the Maine Department of Health and Human Services, Maine Department of Inland Fisheries and Wildlife, and the Maine Department of Agriculture's Board of Pesticide Control which will assist them in submitting the necessary information for the permit.

Marc Bellaud
Vice President/Aquatic Biologist
Aquatic Control Technologies, Inc.
11 John Road
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(508)-865-1000

The LAWPC has chosen Aquatic Control Technologies, Inc. (ACT Inc.) to be the Pesticide applicator. ACT Inc. will be responsible for providing the Response Procedures section of the PDMP, including Spill Response Procedures, Adverse Incident Response Procedures, Record Keeping, and Reporting Requirements.

Sid Hazelton, P.E.
District Engineer
Auburn Water District
268 Court St.
Auburn, Me. 04210

shazelton@awsd.org
(207)-784-6469

Sid Hazelton is responsible for assembling the information provided, and preparing the PDMP and application permit for submission to the Maine Department of Environmental Protection.

C. Person(s) responsible for developing, revising, and implementing corrective actions and other effluent limitation requirements.

Kenneth J. Wagner, Ph.D.
Certified Lake Manager
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144 Crane Hill Road
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Should corrective actions and other effluent limitation requirements become necessary in the course of the algaecide application, Dr. Kenneth Wagner from WRS LLC, and Dan Bisson from CDM/Smith will be responsible for providing this information within the permit limitations.

SECTION 3: Problem Identification

(See Attached Report)

Algicide Application Plan for Lake Auburn

Background

In 2011 and 2012, Lake Auburn experienced increased levels of turbidity at the intake to the water treatment plant; levels approached 5 NTU, which is the compliance criterion for the current filtration avoidance record. Analysis of available water quality information strongly suggests that the increased turbidity in the late summer and fall is linked to increased concentrations of certain cyanobacteria (blue-green algae), specifically *Microcystis* and *Anabaena*. Another cyanobacteria, *Gloeotrichia,* has also recently been found in the lake; it has been present for perhaps 6 years, but was documented to be abundant only in the last two years (2011-2012). While Gloeotrichia's occurrence does not correlate with periods of increased turbidity, it is possible that it could contribute to nutrient increases in the upper levels of the lake and thus fuel algal blooms of late summer and fall.

Data from 2011-12 indicate *Gloeotrichia* appears as early as May, but peaks in August and declines through September (Ewing et al., 2012; unpublished research). It is known from research elsewhere to germinate at the sediment-water interface and rise from areas where light penetrates. The expected water depth range of maximum contribution is 0 to 4.6 m (0-15.2 ft) in Lake Auburn, but may extend to a depth of 13 m (43 ft). It appears that germination takes place over an extended time period in Lake Auburn, but the relative contribution to total *Gloeotrichia* from rising colonies vs. growth and reproduction once colonies have reached surface waters is not known for this lake. In other lakes, uptake of nutrients has been estimated to be an order of magnitude lower once the colonies reach the upper waters than it was when they were growing on the sediment before rising, so killing this alga before it rises to the surface may be a valid strategy.

Anabaena and *Microcystis* are believed to have become dominant phytoplankton in the late summer and fall in only the last two years (2011-2012), and become abundant as the *Gloeotrichia* dies off, though this sequence may not be causative. Peak abundance occurs in September or October, and the highest turbidity values correspond to blooms of these cyanobacteria. In the absence of these cyanobacteria, turbidity values have averaged <1.0 NTU, with <4% of peak values exceeding 1.0 NTU and few values higher than 2.0 NTU. With *Anabaena* and *Microcystis*, visible surface scums form during calm conditions and around the periphery of the lake and average turbidity exceeded 2.0 NTU for 19 days in 2011 and 27 days in 2012, all in September and October. Both *Anabaena* and *Microcystis* come in smaller units (colonies or filaments) than *Gloeotrichia*, and so provide more turbidity per unit mass (with turbidity being a function of both mass and particle size). Thus, these algae appear to represent the primary threat to compliance with the filtration waiver for Lake Auburn as a drinking water supply, and thus a threat to the public health of nearly 60,000 consumers. In addition to public health concerns, this cycle of algal blooms also may contribute to anoxic conditions that are harmful to Lake Auburn's cold water fishery. Other peak turbidity values (maximum of 3.3 NTU, but with averages rarely over 1.0 NTU) appear to be associated with diatom blooms, mainly in the fall.

A succession of cyanobacteria is common in lakes with elevated nutrient levels, and just which cyanobacteria dominate in what order is usually a function of N:P ratios. It is also known from other lakes that *Gloeotrichia* can bring enough phosphorus from the sediment with it into the upper waters to potentially support blooms of other algae when the *Gloeotrichia* dies off. For Lake Auburn, while calculations suggest that this mechanism is possible here, the limited, available data indicate no major increase in total phosphorus during increasing *Gloeotrichia* concentrations, but rather that the total phosphorus level increased after the *Gloeotrichia* peak.

The mechanism for the increase in phosphorus is not known for sure, but may be a function of both watershed inputs and releases from sediment, aided by wind mixing. The increase in 2011 occurred in August and was concurrent with the passage of Hurricane Irene. In 2012, an initial rise in phosphorus occurred in June, which was a very wet month with elevated watershed inflows. There was an additional and additive peak in late September and early October, possibly related to sediment release and water column mixing. In general, the increase in total phosphorus in late summer corresponds to the time of year when surface waters are cooling and may more easily mix with bottom water in response to wind events. There is more than enough phosphorus in the deeper (deeper than approximately 10 m water depth) sediments to fuel blooms if that phosphorus in sediments is released under low oxygen conditions and transported upward. However, the die-off of *Gloeotrichia* corresponds to lower oxygen levels in deeper water that may stimulate the release of phosphorus from the sediment and later mixes with surface water during cooling and windy periods, so we cannot rule out *Gloeotrichia* as a causative agent in the *Anabaena* and *Microcystis* blooms. Nevertheless, the immediate problem for maintaining adequate water clarity (low turbidity) and protecting the public health appears related directly to *Anabaena* and *Microcystis*, not *Gloeotrichia*.

Ideally, management would consist of reductions in nutrient loading to decrease total phosphorus below levels that support blooms (generally around 10 µg/L) and increases in the N:P ratio to values >20, which favors algal forms more easily consumed by zooplankton, like greens and diatoms. It will take time to determine the best course of action for longer term nutrient input control, but there is an immediate threat of non-compliance if cyanobacterial blooms continue in 2013 and beyond. Algicide treatment would provide an interim means to maintain water clarity while nutrient reduction measures were being implemented. Algicide treatment could focus on *Gloeotrichia* if it is a causative agent, and/or on *Anabaena* and *Microcystis*, which generate the highest turbidity levels and threaten compliance with the Safe Drinking Water Act and related filtration waiver. In addition, increased phosphorus levels in the lake also have the potential to fuel diatom blooms in the cool weather months; to date only sporadic instances of elevated turbidity have been observed in these months. In the short term, algicide treatment for diatom blooms is also possible if this were shown to be a cause for concern.

Overview of Treatment Approach

The application of an algicide could directly kill algae in the target treatment zone, if the algae are susceptible to the algicide, the dose is adequate, and the contact time is sufficient. Application of an appropriate algicide over an area large enough to make a difference to algal levels at the water supply intake over an extended period of time would be expected to help maintain low turbidity at that intake. The proposed treatment is intended to minimize the impact of the killed, targeted algae on oxygen, taste and odor, and overall system ecology by treating before biomass becomes excessive. To accomplish this, the timing of treatment will coincide with the exponential growth phase of the algae, as shown in Figure 1. In other words, the treatment would occur while the target algae are actively increasing in abundance but before a bloom condition is reached. Killed algae will settle to the bottom, some nutrients and other substances will be released, and some oxygen demand will be exerted in the bottom water of the lake, but these impacts are expected to be much less than if the algal bloom is allowed to develop and die out naturally. It is very important to recognize that by treating before biomass is substantial, negative impacts are minimized, and overall risk to system ecology is reduced. If nutrient resources remain abundant, other algae may grow and repeat treatment could be necessary, but for a treatment performed in September or even October, this is very unlikely.

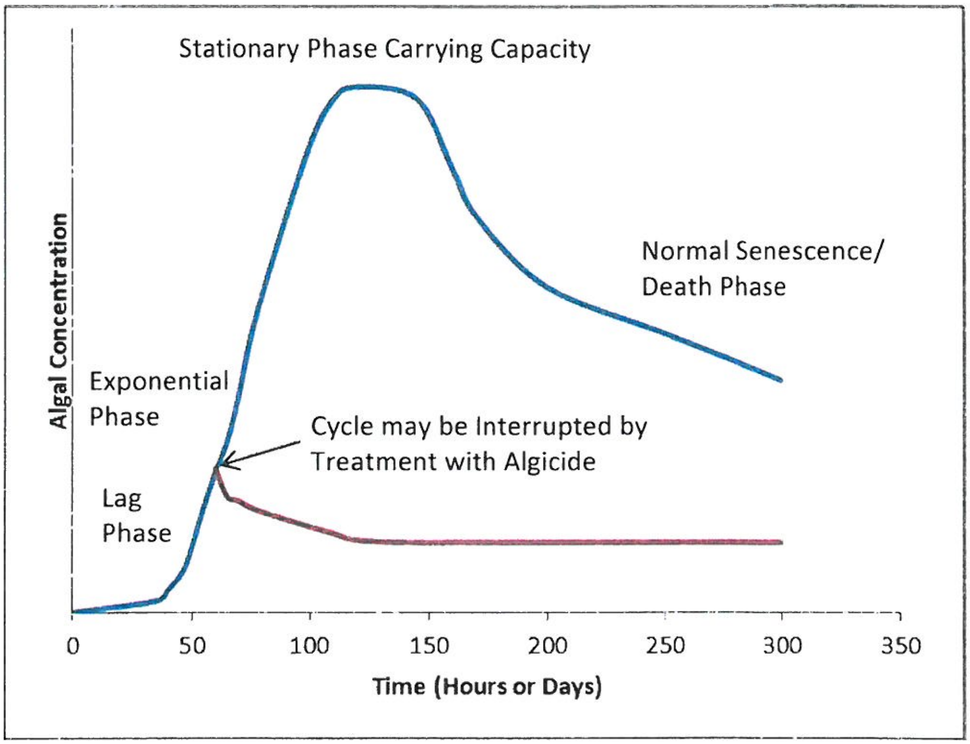

Figure 1. Phases of Algal Growth

If water movement induced by wind or inflows carries new, untreated, algae-laden waters to the intake area, additional treatment may be needed. The intent of treatment is to adequately treat a large enough area to avoid needing further treatment, while not treating more than necessary. The treatment plan must therefore contain a series of steps and maintain flexibility to address multiple possible scenarios while attempting to minimize actual treatments in the course of maintaining acceptable conditions. Key steps include choice of algicide, dose, and target area, pre-treatment assessment of conditions with adjustment of the treatment as warranted, timing of treatment, and monitoring.

Algicide to be Applied

The vast majority of algicide applications involve forms of copper or chemicals that produce peroxide. Other algicides involve synthetic compounds of elevated toxicity to non-toxic organisms (e.g., endothall) or are intended for use on filamentous green algae (e.g., flumioxazin) that are not a problem in Lake Auburn, and are therefore not considered here. Peroxides are newer, less frequently used, and considerably more expensive than copper, but do appear to preferentially attack many forms of cyanobacteria. Peroxides act mainly by dissolving cell walls, with diatoms and some green algae having more resistant cell wall composition than most other algae, including many cyanobacteria. However, extensive mucilage around some cyanobacteria may limit the effectiveness of peroxides. Testing of peroxides with the summer-fall algal assemblage in Lake Auburn would seem appropriate, but for at least 2013 it would seem preferable to use an algicide with a longer track record of success and potential applicability to a wider range of possible problem algae.

Copper is the oldest algicide in use, with over 60 years of application history. It is toxic to many life forms by multiple modes of interaction, all related to some form of absorption into cells with subsequent cell damage and death. For algae, disruption of photosynthesis, inhibition of nitrogen processing to build proteins, and cell wall damage are the three most cited modes of action. For sensitive non-target organisms, such as trout or zooplankton, toxicity includes interference with the absorption of oxygen from the water. For fish and benthic invertebrates in particular, damage to sensitive gill tissues can be lethal. Toxic properties of copper are greatly modified by other features of the water, however, including alkalinity, dissolved or suspended solids and temperature. Colder temperatures and higher amounts of dissolved or suspended solids reduce toxicity. Various species and even populations within species have varying tolerance as well, such that simple generalizations and thresholds are not completely reliable when considering toxicity. Toxicity should be considered as a distribution of possible impacts, not a yes-no issue. Fortunately, many algae are killed at levels of copper low enough to represent a limited threat to other non-target organisms.

Copper comes in multiple forms, the most common and basic being copper sulfate ($CuSO_4$). Copper sulfate is generally prepared in a hydrated form, the most common of which is copper sulfate pentahydrate ($CuSO_4 \times 5H_2O$). Other forms of copper are mostly complexed with some agent that helps them stay in solution longer or aids the activity level, especially where other substances in the water may inactivate the copper rapidly by reacting with it. Waters with high suspended solids content, particularly clay-based solids, reduce the effectiveness of copper. The conditions in Lake Auburn suggest no interference with copper activity, and keeping the copper in solution for an extended period of time is not preferred. What is preferred is a rapid reaction with algae and quick loss from the water column of reacted copper. Consequently, copper sulfate would be the preferred algicide in this case.

The State of Maine registers products by label. In other words, copper sulfate is not specifically approved for use in the state, but rather specific products containing copper sulfate are approved. Additional products may be approved, but at this time the algicide brands containing copper sulfate that are known to be approved for use in Maine, including four that are NSF 60 certified, include:

- Crystal plex
- Pond Boss (NSF 60 Certified)
- Earthtec (NSF 60 Certified)
- SeClear (NSF 60 Certified)
- Crystal Blue
- Algae X
- Triangle (NSF 60 Certified)
- AB Brand

These formulations contain other ingredients as well, mostly inert, but sometimes with other properties of interest. For example, SeClear contains an unidentified phosphorus binder intended to minimize recycling of phosphorus after the algae are killed. Cost may vary substantially among brands. Based on the conditions in the lake and the available copper formulations, we recommend a simple copper sulfate pentahydrate addition.

Dose

The dose of copper can be expressed multiple ways, depending on the formulation. Often one can find the dose expressed as copper sulfate pentahydrate, which is four times the actual mass of copper involved. Here we will express all doses as copper, and those evaluating this treatment should be very careful to do the same.

Necessary copper doses to kill algae can vary from <0.05 mg/L to upwards of 10 mg/L, depending on the target algae and treatment conditions. Based on many years of product development and application history, copper doses <1.0 mg/L are specified on most product labels (although often converted into a concentration of the labeled product, not copper alone). MWRA has a long history of sporadically applying copper sulfate to Wachusett Reservoir, which like Lake Auburn has a filtration avoidance waiver. MWRA typically targets golden-brown or blue-green algae for control of taste and odor with typical target doses between 0.07 and 0.15 mg/L. In other northeastern lakes, doses of copper in excess of 0.1 mg/L are rarely applied, as alkalinity, solids, and other interfering factors are limited. The recommended copper dose for *Anabaena* and *Microcystis* is between 0.05 and 0.13 mg/L, from a range of product literature.

While the anticipated need for algicide treatment in Lake Auburn focuses on cyanobacteria, the reason for the treatment is to limit turbidity and protect the public health by maintaining compliance with the filtration waiver for drinking water supply, and any algae that cause increased turbidity may be targeted. Aside from the cyanobacteria, diatoms may bloom in spring or fall and could achieve high enough densities to raise turbidity to a level of concern. Diatoms known from Lake Auburn that might cause blooms are sensitive to copper at levels no greater than 0.25 mg/L, with most sensitive at <0.10 mg/L.

Actual treatments for cyanobacteria in the northeastern USA typically target a dose of 0.05 to 0.10 mg/L and treat no more than half the water body in a single treatment. Typical results involve 50-90% reduction in the target algae with one initial treatment and 0-1 follow-up treatment in the same year for water bodies where half the area has been treated. Some treatments target just coves where cyanobacteria accumulate, in which case more frequent treatments may be needed as water from elsewhere in the lake moves into the target area after treatment. In some cases more than half of the lake has been treated, but usually with some time in between treatments of smaller portions of the lake. In some cases treatments are more frequent, and it would appear that there is either a constant source of algae to the lake or resistance by the target cyanobacteria. There is therefore an interaction between dose and treatment area that must be considered when planning a treatment (see Target Area section below).

Many of the treatments in northeastern USA waters are for lakes with longer and more severe histories of cyanobacteria blooms than for Lake Auburn. Many are annual repeat treatments where watershed controls to limit nutrient inputs have not been completed for various reasons, or where internal recycling is substantial and so far unabated. For an initial program of algal control in Lake Auburn, a dose no higher than 0.10 mg/L is projected to be necessary, and it may be possible to treat at 0.05 mg/L. Again, toxicity is not a yes-no issue, but rather a distribution; a balance must be struck between adding enough copper to kill enough algae to maintain compliance while minimizing non-target impacts. Here we seek approval for a dose of up to 0.10 mg/L as copper, with pre-treatment assays to be conducted just prior to treatment to determine if the dose can be reduced and still achieve the desired result. This dose should be adequate to kill most of the target algae in a short (1-2 day) period with limited impacts to non-target organisms.

A review of EPA's 1984 Ambient Water Quality Criteria (AWQC) for copper indicates that the most sensitive fish to copper in Lake Auburn are salmonids, specifically lake trout or Togue (*Salvelinus namaycush*) and Atlantic salmon (*Salmo salar)*. The AWQC provides acute toxicity data for Atlantic salmon and brook trout (*Salvelinus fontinalis*); although lake trout are not listed, brook trout are in the same genus and the response to copper should be similar. Acute toxicity is expressed as a species mean acute value (SMAV) LC50, the dose at which 50% of the population dies, normalized to 20 °C and 50 mg/L hardness.

The SMAV LC50 for copper for juvenile Atlantic salmon is 0.197 mg/L; for juvenile brook trout the SMAV LC50 for copper is 0.110 mg/L. Hardness in Lake Auburn is likely less than the 50 mg/L used to normalize the SMAV toxicity levels, so toxicity could be increased somewhat in Lake Auburn. However, Lake Auburn is stocked with adult lake trout and Atlantic salmon, which are less sensitive to toxins than juvenile fish, suggesting less potential for acute toxicity. A very low risk to the fish community is projected, even without consideration of any spatial separation of the deep-dwelling salmonids and the proposed shallow-water treatment zone. Salmonids can escape treated areas and will have plenty of untreated lake to occupy if any threat is perceived; copper at a level high enough to cause toxicity is expected to elicit a flight response.

Some zooplankton and benthic invertebrates are listed as being impacted by copper levels of 0.01 to 0.02 mg/L, but most impacts begin around 0.10 mg/L, with increasing impact up to about 0.5 mg/L. There is therefore some risk to zooplankton and benthic invertebrates in Lake Auburn at the recommended dose range of 0.05 and 0.10 mg/L, but as no more than half the lake will be treated, entire populations are not at risk, and with high reproduction rates any impacted areas are expected to soon be repopulated. Previous experience with copper treatments has not indicated any significant or lasting impacts on zooplankton. Many lakes treated with copper have been found to have thriving populations of a variety of zooplankton, and reduction in cyanobacteria has been observed to be beneficial to population growth. Only one known treatment in recent years in New England demonstrated some toxicity to mollusks, and unusual conditions that concentrated copper in shallow water were suspected in that case.

Proposed Surface Treatment for Cyanobacteria or Diatoms

Target Areas

The target area will depend upon the target algae. Algicides have regularly been used to blue-greens like *Anabaena* and *Microcystis* and diatoms in surface treatments covering areas around water supply intakes that represent some number of days of supply. For larger treatments, no more than half the lake is typically treated. For Lake Auburn, it is requested that an initial treatment of up to half the lake

(456 out of 912 ha, or 1140 out of 2282 ac) be approved, with this treatment divided into two 228 ha (570 ac) zones, with the option to treat either or both zones as warranted by conditions. This would cover an area large enough to potentially eliminate turbidity concerns for the year with a single treatment while providing refuge areas for potentially impacted organisms.

Animations of water movement in Lake Auburn produced by the three-dimensional model developed by ERM (CDM, 2006) indicate that a clockwise circulation pattern in the horizontal direction is the most common one observed. Given that pattern, the shape of the treatment area should favor the northern and eastern parts of the lake (Figure 2).

For *Anabaena* and *Microcystis*, treatment of the upper 3-6 m (10-20 ft) of the water column would be the preferable treatment area. As all of the target cyanobacteria are buoyant, the upper 3 m will contain the vast majority of those algae once germinated from resting stages. If conditions are very calm, most of these algae may be present in the upper 1.5 to 2 m of the water column, but calm conditions cannot be counted upon for any substantial amount of time at Lake Auburn. It could be necessary to treat a 6 m layer, starting at the surface, if mixing is substantial.

Zone 1 would be the primary treatment area, with discretion given to AWD/LWD and applicator to treat in Zone 2 as conditions warrant, based on evaluation of conditions and treatment progress at the time of treatment. For example, if algae are increasing rapidly all over the lake, wind and current suggest relatively rapid mixing across the lake, and/or treatment does not markedly reduce turbidity, both zones may require treatment. However, if algal tracking shows a very gradual increase, conditions remain calm, and clarity improves dramatically upon initial treatment, only Zone 1 may require treatment.

Any refinement of the treatment area for *Anabaena* and *Microcystis* depends on concern for copper at the drinking water intake and the magnitude and prevailing direction of wind-induced currents and inlet-induced flow on the movement of untreated water still containing undesirable algae. Copper <1.0 mg/L is not a concern for human health, so the treatment with <0.10 mg/L could occur adjacent to the intake based on concentration alone. For anyone using lake water (direct or via the Auburn and Lewiston supply systems) for irrigation, copper at <0.10 mg/L is not a concern. If there is concern for incomplete mixing during treatment or just public perception, then an untreated buffer zone can be established around the intake. Based on an average intake withdrawal of 6.5 mgd and complete mixing in the epilimnion (the intake is located in 18 ft of water within the epilimnion), only 0.3 ha (0.8 ac) of area is needed to provide a day of supply, while 1.0 ha (2.4 ac), 2.1 ha (5.3 ac), or 4.3 ha (10.8 ac) would provide 3, 7 or 14 days of supply, respectively (Figure 3). It is important to note that copper does not present a human health concern until beyond a tenfold increase over the targeted treatment concentration. With the low copper concentration to be applied relative to human health and irrigation concerns, no buffer appears necessary and no buffer is proposed.

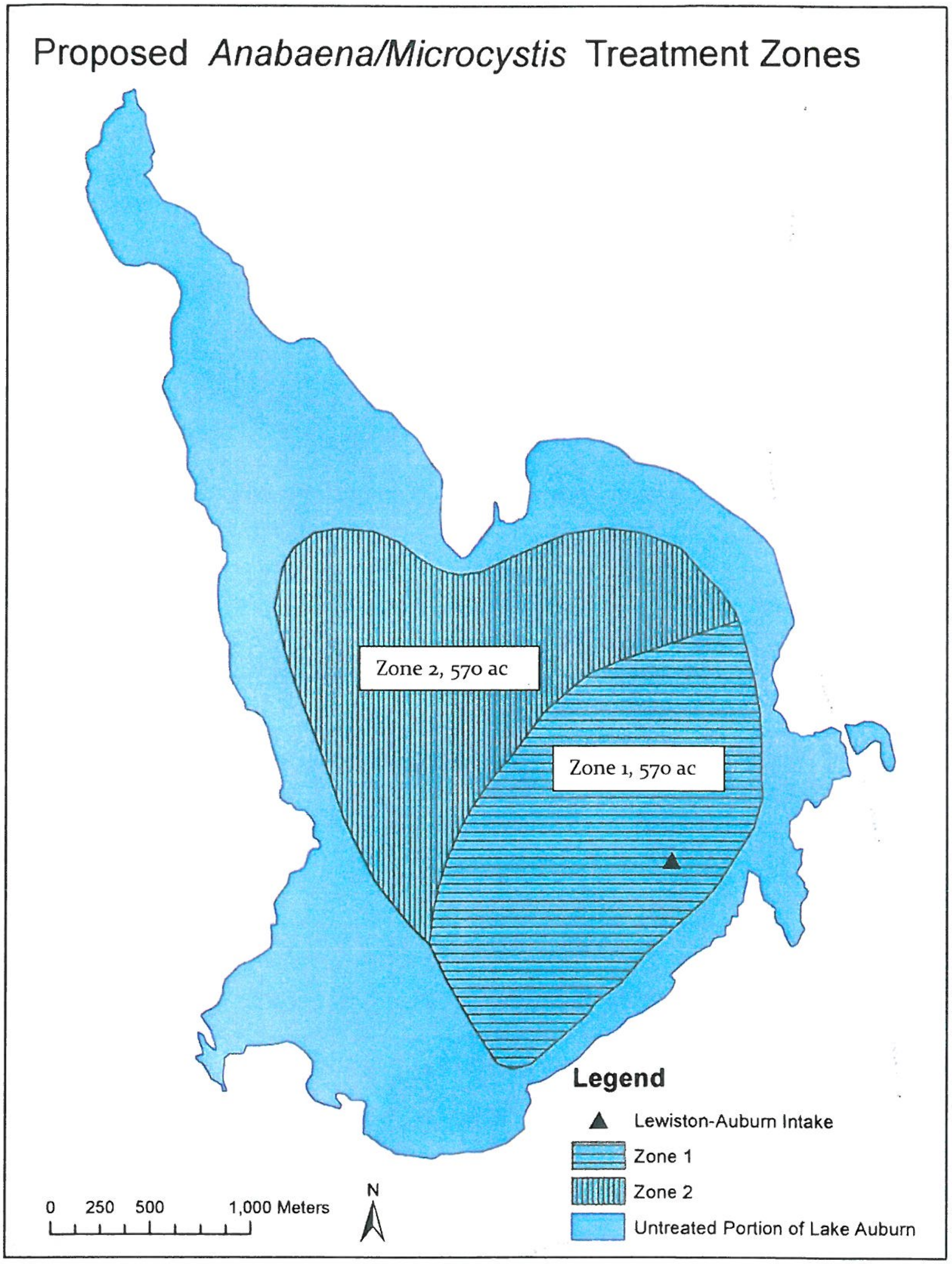

Figure 2. Proposed Treatment Zones for Surface Copper Application

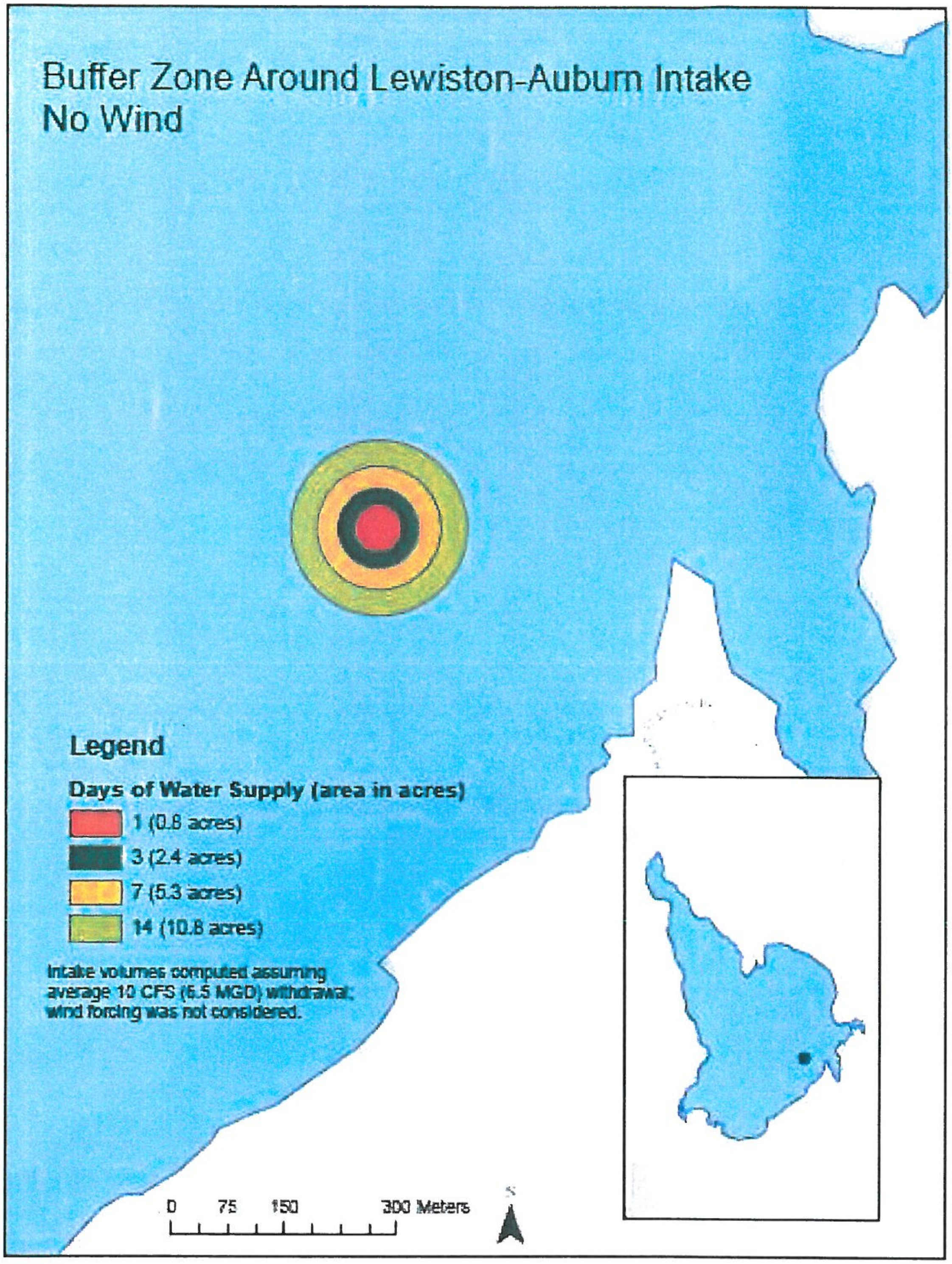

Figure 3. Buffer Zone around Water Supply Intake to Limit Copper Intake

Treatment Timing

The timing of treatment will be linked to detected increases in algae, as measured by turbidity and visual observation as a surrogate and supported by algal analysis. Treatment of *Anabaena* or *Microcystis* (or diatoms) would be triggered by an increase in turbidity to a level >1.5 NTU as a rolling two-day average with corroboration by algal analysis. At a minimum, daily tracking of turbidity and weekly tracking of algae in late summer in Lake Auburn will provide notice of increasing cyanobacteria. The contracted applicator is expected to mobilize and treat within a week, during which lab testing of copper sulfate concentrations can be conducted to determine the lowest effective concentration that can be used. Vertical distribution of algae can also be assessed during the mobilization period, allowing a decision on what portion of the possible 6 m (20 ft) layer will be treated. Treatment of Zone 1 (228 ha, 570 ac) would be conducted in no more than 3 days, and assessment of the extent of algae distribution around the lake prior to treatment and the result of treatment will inform a decision as to whether Zone 2 should be treated.

A permit for copper application would potentially allow for multiple treatments in a six-month period, so the above process may be repeated. In cases similar to Lake Auburn, it is unusual to have more than two treatments in a season, and more typical to need only the initial treatment to make it through the growing season. With *Anabaena* and *Microcystis* occurring mainly in late summer and early fall in Lake Auburn, it is expected that a single treatment will be adequate, but provision for one follow-up treatment is requested as a contingency.

Pre-treatment Assessment

Prior to any treatment, the algal data would be assessed along with any other relevant water quality data. While bi-weekly sampling of algae is recommended throughout the growing season, weekly sampling should occur during expected growth periods for target algae. Samples will be collected at five horizontal locations and as two composites at each location, one in the upper waters and another in the transition zone (near the thermocline). Turbidity and other easily assessed water quality variables are measured daily for intake water, and additional measures are made in the lake on a weekly to biweekly basis. Because cyanobacteria can rise from the sediment-water interface fairly quickly, there is no guarantee that a gradual rise in algae counts will occur, or that an early warning of an impending bloom will be given, but the data available currently for Lake Auburn suggest that bloom formation is not rapid and early warning may indeed be given and facilitate the desired treatment scenario. Turbidity does not rise above an average of 1.5 NTU except when a bloom is forming, and has taken one to three weeks to reach peak levels after exceeding 1.5 NTU.

Once there is indication that a treatment will be needed, it will be important to better characterize conditions in Lake Auburn with regard to the treatment. The distribution of turbidity and algae over the area of the lake, especially in the potential treatment zones 1 and 2, should be assessed during the applicator mobilization period, allowing preliminary determination of whether both zones or just zone 1 will be treated. Samples from the treatment zones should be brought into the lab and treated with 0.05, 0.075 and 0.10 mg/L of copper and the results assessed, allowing determination of the lowest effective dose.

Treatment Protocols and Monitoring

The applicator will maintain compliance with the MEPDES permit, which includes provisions for algicide storage, spill prevention and response, application, dose control, and related activities to ensure that the right amount of algicide is applied to the proper location at the proper dose in the correct timeframe. The MEPDES permit and the algicide label govern all aspects of actual treatment.

The target concentration for the algicide will be determined within two days of the treatment, based on lab assays with the actual algal assemblage. The recommended concentration is planned to be between 0.05 and 0.10 mg/L.

For treatment of *Anabaena, Microcystis*, or diatoms, initial determination of whether only zone 1 or zones 1 & 2 will be treated will be made based on the extent of algal conditions across the lake and predicted weather conditions, mainly as relates to water movement. The order of treatment if zones 1 & 2 will be treated will be determined by the applicator in conjunction with AWD/LWD depending on weather conditions (as relates to application efficiency and safety and direction of water movement). If an initial decision to treat only zone 1 is made, a final determination will be made at the end of treatment based on conditions in the treated area, mainly as pertains to increased clarity (reduced turbidity), change in algal composition, and relative conditions in zone 2. If it is felt that the improvement in zone 1 is not sufficient to mediate any effects from mixing with zone 2, treatment of zone 2 can commence. The primary criterion will be maintenance of turbidity at an average <1.5 NTU.

Actual application involves on-board mixing of granular copper and water to make a concentrated tank mix, blending with lake water for dilution to create the actual discharge, discharging at some controlled rate, dispersing the discharge over some width of application area, controlling the speed of the application vessel, and maintaining a set distance between vessel pathways during application. These activities are to result in achieving the target concentration in the target area.

Copper sulfate will be tank mixed on the application vessel with water from Lake Auburn and further diluted with lake water (usually in a Venturi suction arrangement) prior to discharge. Discharge of the aqueous copper solution will be spread so as to maximize mixing and limit high concentrations to the extent practical. For surface applications, typical application scenarios involve spray application systems that dilute the tank-mixed copper concentrate by at least tenfold then spread it over a width of 10 to 15 m (33 to 50 ft). With surface water used to mix and discharge the copper, thermal gradients maximize lateral spreading, but the increased density of the copper-water solution promotes sinking, resulting in advantageous mixing horizontally and vertically. Initial surface concentrations will be in excess of 1 mg/L, but will dilute to the target concentration within minutes.

A typical vessel speed is 8-13 kph (5-8 mph) and the distance between application vessel passes is usually 30 to 60 m (100-200 ft). Once the tank mix and discharge rate are set, with a set width of the discharge pattern, it is vessel speed and distance between passes that are usually altered to meet concentration targets. The depth of treatment will be determined based on ambient conditions expected during treatment, and will occur over a range of 3-6 m (10-20 ft), as determined mainly by vertical distribution of algae shortly before treatment and anticipated wind and inflow (and related mixing) conditions. Discharge of algicide will occur in a manner that maximizes mixing over the targeted depth range.

Monitoring will be conducted by AWD/LWD or a designated agent during treatment. Visual observation for dead, dying or distressed organisms, especially fish, will be conducted within 24 hours before any treatment commences, on each day of treatment, again the day after treatment, and one week after treatment. For zones 1 and 2, phytoplankton samples are to be collected at the standard AWD/LWD sampling locations within the actual treatment zone (supplemented by additional locations if only Zone 1 is treated) and one location not to be affected by treatment within 24 hours before treatment commences, again the day after treatment, and again one week after treatment, with samples as composites of the upper 6 m (20 ft) of the water column.

Lakewide zooplankton impacts are not expected, but samples will be collected at each site and time of phytoplankton sampling as a net tow sample covering the upper 6 m of the water column. These samples will be used for rapid assessment of phytoplankton conditions, especially during treatment, for the purpose of corroborating turbidity changes and determining if zone 2 should be treated, if such treatment was not included in the initial treatment. The net tow samples can be preserved and held for later examination if there is any indication of toxicity from copper from visual assessment of net tows.

Dissolved oxygen will be assessed at a minimum of 3-m (10-ft) intervals from surface to bottom within 24 hours before treatment commences and again one week after treatment is complete at the phytoplankton and zooplankton sampling locations within each treated zone and a location not influenced by treatment with similar depth. Normal weekly monitoring for the suite of water quality variables assessed by AWD/LWD will continue before, during and after treatment, with at least one station within the treatment zone (a station is to be added if routine monitoring stations do not cover the treatment zone).

Samples for measurement of copper concentrations will be collected from 5 locations within the area treated on any day, once within 30 minutes of treatment at the sampling stations and again near the end of the treatment day. An additional sample will be collected one day later and one week later at the same locations. Samples will be composites of the upper 6 m (20 ft) of the water column.

Contingencies

The above treatment plan elements are intended to guide the treatment, maximizing success and minimizing non-target impacts. Unusual weather conditions, rapid increases in algal concentrations, or other unforeseen circumstances are possible, however, and the applicator and AWD/LWD are to be afforded maximum flexibility in conducting treatment within the appropriate range of established thresholds for the treatment. For example, the exact timing of treatment, spacing of vessel passes, and width of the discharge apparatus may be altered for good reason, including weather conditions and observed algicide dispersal. The average copper concentration should not exceed 0.10 mg/L, but it should be recognized that some variation around that average is to be expected during treatment. Any significant deviation from the treatment plan is to be discussed with the assigned regulatory official(s) in advance if at all possible, but reasonable adjustments that improve treatment effectiveness or safety should be allowed. It is important that all parties understand that not all conditions can be known ahead of time and that field adjustments may be necessary.

Concern for adverse impacts on non-target organisms is heightened by warm water temperatures, low oxygen levels, and high algal densities. Killing large amounts of algae in warm water with low oxygen levels can cause mortality of animal life, independent of any toxic effects of copper. This treatment program has been set up to avoid high algal accumulations at the start of a treatment, and all involved parties must recognize that delays between treatment triggers and actual treatment may increase risk to non-target organisms or limit treatment effectiveness. Cooperation, responsiveness and flexibility are needed.

Potential Experimental Treatment of *Gloeotrichia*

It has been suggested in multi-party discussions that treating *Gloeotrichia* before it becomes abundant might limit impacts later in the summer. The *Gloeotrichia* bloom does have the potential to deliver additional phosphorus to the surface waters, although peak phosphorus concentrations do not correlate to peak *Gloeotrichia* density. The decline of the *Gloeotrichia* bloom does add oxygen demand to an already stressed bottom water layer; although there is no proof that this represents a key influence in the loss of oxygen observed in 2011 and 2012. Still, the rise of *Gloeotrichia* is the first in a series of algal blooms that resulted in low turbidity in 2011 and 2012, and trying to prevent that series of events from the start deserves consideration.

If it is desired to minimize *Gloeotrichia* accumulation, copper could be used as the algicide. Treatments specifically targeting *Gloeotrichia* have not been conducted anywhere in New England that we could ascertain, but *Gloeotrichia* is sometimes present in treated lakes. Few copper products list an appropriate dose for *Gloeotrichia*, but those that do list a range similar to that for *Anabaena* and *Microcystis*. Consequently, copper sulfate pentahydrate is recommended as the algicide at a dose between 0.05 and 0.10 mg/L.

A treatment would occur upon observation of *Gloeotrichia* appearance at the lake surface, most likely in May or June. This would signal the germination of resting stages. However, it is not known at this time if a copper treatment will prevent most further germination in the targeted zone, or if the treatment benefits would be transient (a week or two), after which previously ungerminated resting stages might germinate. Multiple treatments may therefore be necessary to substantially depress resting stage germination. This is experimental work that might best be conducted in limnocorrals, top to bottom enclosures that can be set out in the lake and treated with minimal impact to any area outside the limnocorrals. But if there is an interest on the part of the regulatory community in attempting a larger treatment before more research is conducted, an approach is provided here for consideration. Additional study of *Gloeotrichia* germination and growth patterns over space and time will likely be needed to better plan a treatment if it is concluded that treatment is needed, but having approval in place could allow testing that will advance our knowledge significantly.

Because of their different life histories, there is a distinct dichotomy between the favored approaches for *Gloeotrichia* vs. *Anabaena/Microcystis*. If *Gloeotrichia* is to be treated, it would appear best to attack the germinating resting stages, and this could be accomplished by injecting copper sulfate through weighted hoses near the sediment-water interface. As the contribution of *Gloeotrichia* resting stages is thought to decrease with depth beyond the point of approximately 30% surface light levels, treatment in Lake Auburn would focus on the area between shoreline and 4.6 m (15.2 ft) of water depth based on typical late spring Secchi depths. However, treatment of water up to 13 m (43 ft), which is twice the Secchi depth and the 1% light penetration level, may be necessary to attack all contributing *Gloeotrichia* resting stages.

With only limited information on the rate of *Gloeotrichia* germination for Lake Auburn and an apparent recruitment period of over two months, it is not clear that a single treatment will kill even a majority of resting stages in the process of germination (which tends to last <1 week), so any treatment in 2013 would be experimental and should probably be restricted to the 0-4.6 m water depth zone. Since it will be difficult to operate treatment vessels close to shore in water <3 m (10 ft) deep, the target treatment area of 180 hectares (450 ac) would include 82.4 ha (206 ac) of near-shore (0-3 m water depth) area that would not be directly treated and another 97.6 ha (244 ac, at 3.0-4.6 m) that would be treated with the expectation that some treated water will spread into the 82.4 ha of untreated target zone (Figure 4). Some spread into deeper areas might also be expected, but certainly not to the full extent of the 13 m depth contour and probably not more than 100 to 200 ft outside the treated zone.

A narrow dispersal system (weighted hoses) is likely to be applied to any benthic treatment, necessitating a slower rate of discharge and a closer distance between vessel passes to meet treatment goals. If a treatment for *Gloeotrichia* occurs, the depth at which discharge occurs will be within 1 m (3.3 ft) of the bottom in the targeted area.

Using a weighted hose and assuming a mixing zone of 3 m (10 ft) in depth, a total of close to 3 million m^3 (2440 ac-ft) of water would be treated for *Gloeotrichia* control. If the bottom water is significantly colder than the water above it, use of that water as the mixing agent may help keep the copper solution as close to the bottom as possible. Chilling the water on the vessel goes beyond anything that has been attempted previously, and adding salts to increase density would be undesirable in a drinking water supply, but some experimentation might be possible to minimize upward dispersal of applied copper.

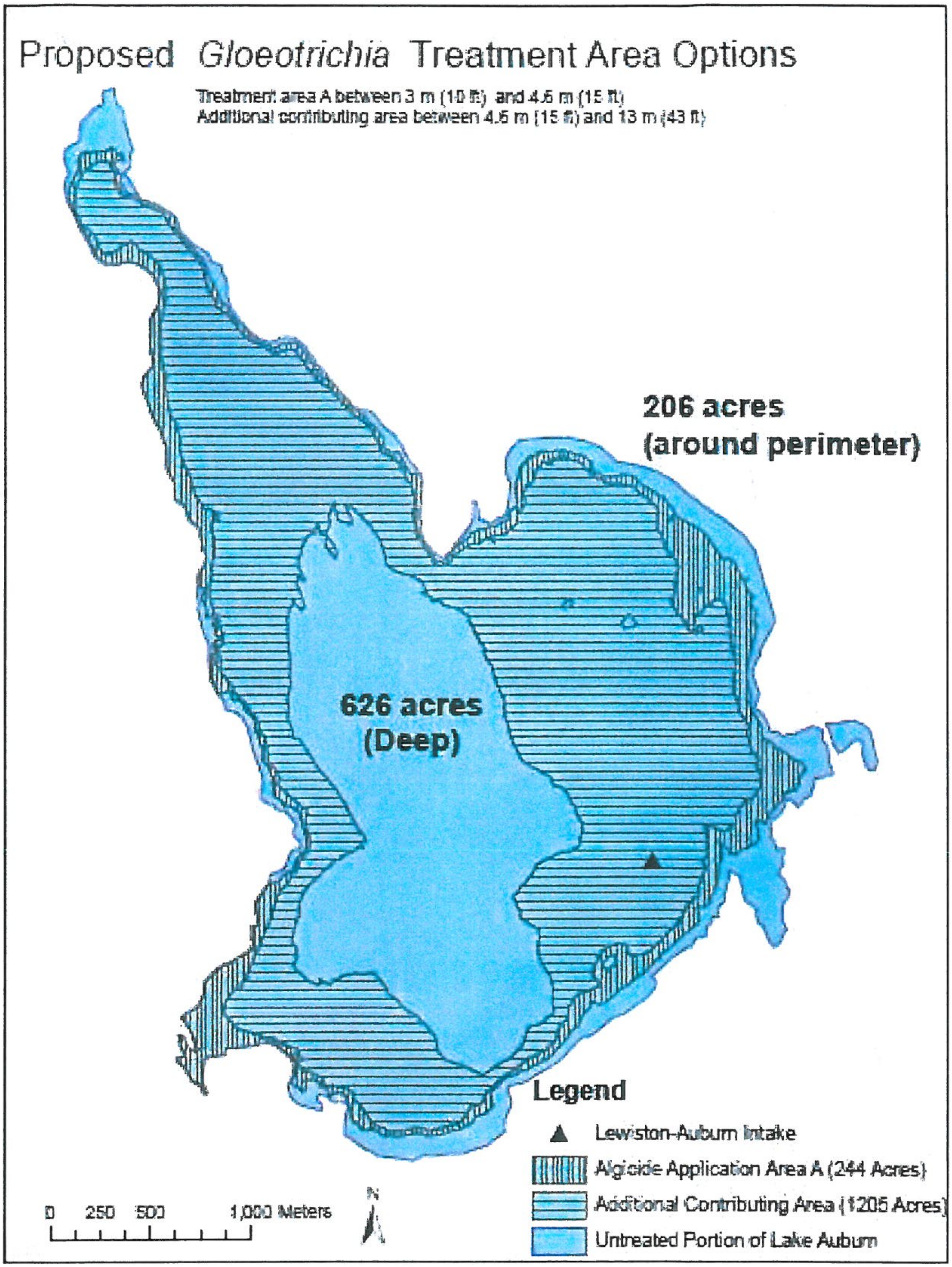

Figure 4. Potential Gloeotrichia Treatment Area in Lake Auburn Treatment Summary

With a concentrated copper solution being injected near the bottom, there is definite risk to mollusks and other invertebrates in the treatment area from a benthic treatment. Actively treating slightly less than 100 ha (250 ac) and anticipating an impact zone of perhaps twice that area means that less than one quarter of the lake area would be treated, limiting potential lakewide impacts to benthic organisms and fish near the bottom in shallow waters at the time of treatment. Risk to populations is not negligible, but does not extend to the whole lake. Treating a larger area to extend the treatment into deeper waters would increase risk to both invertebrates and trout and is not recommended. At a minimum, feeding is likely to be temporarily disrupted, but bioaccumulation of copper is considered to be very low in animals, so longer term impacts to targeted benthic areas should be low. Yet at this stage of investigation and in-lake management planning, a more extensive near-bottom treatment, such as the additional treatment area shown in Figure 4, is not advised.

Monitoring effort would be focused on detection of *Gloeotrichia* increase in the water column. During the period of anticipated germination, visual observations can be made for *Gloeotrichia* on at least a weekly basis, assisted by net tows that concentrate larger particles and make quick assessment easy. Continued weekly monitoring of *Gloeotrichia* colony density is expected to suffice for assessment of any treatment benefit.

Summary of Treatment Approach

Two possible treatment scenarios are envisioned, with the primary effort being a surface treatment targeting the upper 3-6 m (10-20 ft) of the water column over up to half the lake for control of cyanobacteria (mainly *Anabaena* and *Microcystis*) and possibly diatoms. Surface treatment for cyanobacteria or diatoms is commonly performed to reduce algae that increase turbidity in many lakes, and in this case represent a threat to compliance with the terms of the filtration waiver and thus, a threat to public health. A detailed plan for application to Lake Auburn, if needed, has been developed. The plan would treat Zone 1 as shown in Figure 2 with the option to treat Zone 2, if required.

An experimental near-bottom treatment to minimize *Gloeotrichia* recruitment into surface waters is also outlined in the event that regulators want to see the life cycle of this alga disrupted. The *Gloeotrichia* treatment is viewed as experimental, as experience with *Gloeotrichia* treatment is very limited and it is not known that a single treatment will limit germination of resting stages for the rest of the spring-summer period.

Surface Algae Treatment:

- Goal: Disrupt rapid growth of algae in surface waters that causes increased turbidity and threatens compliance with filtration waiver and threatens the public health. A short-term means of lowering turbidity is needed until nutrient sources can be controlled.

- Copper sulfate is to be applied at a dose not to exceed 0.10 mg/L; the exact concentration is to be determined by pre-treatment assays.

- The target area is between 0 and 10 to 20 ft (3 to 6 m) of water depth over an area of 570 acres (228 ha) surrounding the intake, with treatment of another 570 acre contiguous area if needed. Exact depth and area are to be determined just prior to treatment and are adjustable within the requested range during treatment as warranted.

- Timing of treatment will be triggered by an increase in turbidity to >1.5 NTU as a rolling two-day average with corroboration that algae are responsible for the elevated turbidity. This approach is intended to kill algae before significant blooms develop, minimizing impacts to oxygen and non-target aquatic organisms. The greatest concern is with the cyanobacteria *Anabaena* and *Microcystis*, which are expected to reach maximum abundance in September or October.

- Actual treatment will follow MEPDES algicide application procedures to maximize effectiveness while minimizing non-target impacts

- Monitoring is to include standard water quality monitoring already conducted by AWD/LWD, plus additional turbidity, phytoplankton, oxygen and copper measurements in and out of treatment zone.

- The primary non-target organism risk is toxicity to zooplankton in the treatment area. Zooplankton tow samples will be collected as part of rapid phytoplankton assessment and will be preserved and saved for later analysis if there is indication of toxicity.

Experimental Benthic Gloeotrichia Treatment:

- Goal: Limit potential for *Gloeotrichia* to be a causative agent in later cyanobacteria blooms; note that there is uncertainty with regard to ability to stop germination of resting stages with a single treatment in a limited area.

- Copper sulfate is to be applied at a dose not to exceed 0.10 mg/L; exact concentration to be determined by pre-treatment assays.

- The target area is between 0 and 15 ft (4.6 m) of water depth, with actual application to 244 acres between 10 and 15 ft deep, with possible diffusion into 206 shallower acres and into some deeper acreage.

- Application would occur within 3.3 ft of the bottom in the target area.

- Treatment timing would be triggered by the appearance of *Gloeotrichia* at the lake surface, most likely in May, possibly in June.

- Actual treatment would follow MEPDES algicide application procedures to maximize effectiveness while minimizing non-target impacts

- Monitoring of *Gloeotrichia* abundance after treatment would be conducted to determine effectiveness.

- The primary non-target risk is toxicity to benthic invertebrates and disruption of fish feeding in the target area. As these risks appear significant, this treatment might best be conducted on a small scale with limnocorrals unless regulators feel the risk is justified.

References

CDM (2006). Computational Flow and Fecal Coliform Transport Modeling of Lake Auburn. Appendix H in *Turbidity and Bacteria Study Update.* Prepared for Auburn Water District and Lewiston Water Division.

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Copper Sulfate Use in New England and New York

Introduction

Copper sulfate is used commonly as an algaecide for quickly reducing algae populations in water supply reservoirs and has a long history of successful application in New England lakes and reservoirs. It has been used for this purpose for over 60 years and poses a minimal threat to non-target species if applied correctly. Copper is toxic to algae and other aquatic life because it destroys cells causing death; in algae copper disrupts photosynthesis, inhibits nitrogen processing used to build proteins, and damages cell walls. Although copper can have similar lethal effects on fish, benthic invertebrates, zooplankton, and other aquatic life, the relatively low dose required to kill algae represents a limited threat to most non-target organisms.

In New England, copper sulfate algaecides have been used extensively and successfully for over 25 years to control cyanobacteria in water supply lakes and reservoirs. Table 1 lists examples of copper sulfate algaecide applications throughout Massachusetts, Connecticut, and New York from 1986 through 2012.

Target algae have often included *Anabaena* and *Microcystis*, believed to be the main drivers of increased turbidity in Lake Auburn. Throughout this 25- year application history there has been one known application which had observed toxicity impacts to non-target species, which occurred at Lake Singletary in Sutton, MA; localized snail and mussel mortality was noted following one algaecide applications at this lake.

Case Studies – Successful Algaecide Treatment of Water Supply Reservoirs

Two water supply reservoirs in New England with an especially long history of copper sulfate algaecide application are Wachusett Reservoir in central Massachusetts and Lake Cochichewick in North Andover, Massachusetts. This section describes case studies of these two water supply reservoirs that examine how copper sulfate was applied, target concentrations, effects on finished water, impacts to non-target species, and efficacy.

Wachusett Reservoir

Wachusett Reservoir is the terminal reservoir of the greater Boston water supply for communities served by the Massachusetts Water Resources Authority (MWRA) in eastern Massachusetts. Similar to Lake Auburn, Wachusett Reservoir is a cold, dimictic (mixes twice per year) lake used as an unfiltered supply reservoir. Wachusett Reservoir has been treated with copper sulfate to control taste and odor generating algae, typically golden-brown algae (*Synura, Dinobryon*, *Chrysosphaerella*, or *Uroglena)* and the blue-green alga *Anabaena*. MWRA has established an algal control plan that includes regular monitoring and trigger levels for copper sulfate application. Records for copper sulfate applications start in 1986. Table 2 describes the dates, target algae, copper sulfate and copper ion mass, target concentration, and depth for copper sulfate applications from 1995 through 2012. As shown in the table, treatment frequency ranges from none for several years to up to six in a year.

Table 1. Partial List of Copper Sulfate Algaecide Applications to Lakes and Reservoirs in Massachusetts, Conncecticut, and New York

Lake Name	Municipality	State	Lake Area (ac)	Potable Supply (Y/N)	Unfiltered Water Supply (Y/N)	Year(s) Treated	Treatments per Year	Target Algae	Target Cu Concentration (mg/L)	Surface or Deep Treatment (S/D)	% of Lake Area Treated	Duration of Effective Concentration (days)	Duration of Detectable Concentration (days)	Impact on Target Algae	Any Toxicity to Non-Target Organisms (Y/N)	Details of Any Toxic Response
Cochichewick	North Andover	MA	575	Y	N	1988-1991,1993, 2000-2007 , 2009, 2012	1 to 2	Cyanobacteria and other algal species	0.04	S	50	Unknown	Unknown	Eliminated for at least 1 month	N	
Suntaug Lake	Peabody	MA	150	Y	N	2007, 2008, 2009	1	Cyanobacteria (*Microcystis* & *Woronichinia*)	0.03	S	100	Unknown	Unknown	Eliminated for season	N	
Crystal Lake	Wakefield	MA	50	Y	N	1995, 1996, 1997, 1999, 2001, 2002, 2003, 2006, 2007, 2009, 2010, 2012	1 to 2	Cyanobacteria (*Microcystis* & *Anabaena*)	0.08	S	75	Unknown	Unknown	Eliminated for at least 1 month	N	
Haggetts Pond	Andover	MA	215	Y	N	2005-2008, 2010, 2011, 2012	1 to 2	Cyanobacteria	0.06	S	100	Unknown	Unknown	Eliminated for season	N	
Wynona Lake	Peabody	MA	94	Y	N	2009, 2010	1	Cyanobacteria	0.05	S	100	Unknown	Unknown	Eliminated for season	N	
Artichoke Reservoir	Newbury	MA	160	Y	N	2001, 2011	1	Cyanobacteria	0.05	S	60	Unknown	Unknown	Eliminated for season	N	
Beardsley Reservoir	Sharon	CT	75	Y	N	2003	1	Cyanobacteria (Anabaena, Aphanizomenon)	0.06	S	50	Unknown	Unknown	Eliminated for season	N	
Mores Pond	Wellesley	MA	107	Indirect	N	2004, 2010, 2012	1	Cyanobacteria	0.08	S	50	Unknown	Unknown	Eliminated for season	N	
Lillinonah	Danbury	CT	1500	N	N	2004-2010	2 to 3	Cyanobacteria	0.04	S	20	Unknown	Unknown	Algae reduced, replaced in several weeks	N	
Congamond Lakes	Southwick	MA	465	N	N	2003-2010, 2012	1 to 2	Cyanobacteria	0.04	S	10 to 50	Unknown	Unknown	Eliminated for season	N	
Billington Sea	Plymouth	MA	270	N	N	1996-1998, 2000-2002	1	Cyanobacteria (Anabaena, Aphanizomenon), Chlorophyta	0.07	S	80	Unknown	Unknown	Eliminated for season	N	
Pillings Pond	Lynnfield	MA	100	N	N	2004-2012	1 to 4	Cyanobacteria (*Microcystis* , *Anabaena* & *Aphanizomenon*)	0.06	S	50	Unknown	Unknown	Reduced for several weeks	N	
Masscupic Lake	Tyngsboro	MA	200	N	N	2006-2012	1 to 3	Cyanobacteria	0.07	S	50	Unknown	Unknown	Eliminated for season	N	
Copake Lake	Copake	NY	410	N	N		1	Cyanobacteria	0.06	S	33 to 50	Unknown	Unknown	Eliminated for season	N	
Furnace Pond	Pembroke	MA	110	N	N	2010-2012	1 to 2	Cyanobacteria	0.06	S	80	Unknown	Unknown	Eliminated for season	N	
Quaboug Pond	Brookfield	MA	550	N	N	2005, 2006, 2010	1 to 4	Cyanobacteria (*Microcystis* & *Aphanizomenon*)	0.06	S	50	Unknown	Unknown	Eliminated for season	N	
Lake Singletary	Sutton	MA	330	N	N	2003-2011	1	Cyanobacteria (*Microcystis* & *Aphanothece*)	0.05	S	50	Unknown	Unknown	Eliminated for season	Y	Localized snail and mussel mortality noted
Lake Shirley	Lunenberg	MA	350	N	N	2007, 2009, 2011	2	Cyanobacteria (*Anabaena* & *Microcystis*)	0.07	S	50	Unknown	Unknown	Eliminated for season	N	

MWRA typically uses a target dose of 0.1 – 0.2 mg/L copper ion; a $CuSO_4 \times 5H_2O$ formulation is used so the mass of copper ion is one quarter of the mass of copper sulfate applied. Copper sulfate is applied in the area around the intake corresponding to a 3- to 4-day supply, or about 1,000 MG; the target concentrations in Table 2 were calculated assuming this treatment volume. For surface treatment, bags or hoppers are filled with copper sulfate crystals and dissolved into the treatment area. For deep treatments, water is mixed with the copper sulfate and pumped through a hose weighted to direct treatment at the thermocline.

Two studies were conducted to examine the fate of copper applied to the reservoir. In 1995, the study included water sampling at the intake to understand the quantity of copper applied to the reservoir that left the reservoir and sediment sampling to determine if there was a build-up of copper in the sediment (CDM, 1996). In 2001, water sampling was conducted to examine the fate of copper in the reservoir itself (MWRA, 2011). Both studies used a sufficiently low copper detection limit of 0.5 µg/L to allow changes to be discerned; note there are additional copper samples collected prior to 1995 which used a higher detection limit that do not allow effects to be seen. The water sampling programs both show that the copper concentration in Wachusett Reservoir does not increase appreciably following copper sulfate application. Similarly, the sediment sampling program did not identify any build-up of copper in the sediments.

In 1995 water quality samples were collected and analyzed for copper at the intake following a copper sulfate application on June 23, 1995. The background copper concentration was measured the day before copper sulfate was applied, and copper concentrations were tracked for 12 days after application. Figure 1 shows a time series plot of total copper concentration at the intake during the 1995 study. These data indicate that 113 lbs of copper left the reservoir during the 15-day period from June 21 through July 5, 1995. The pretreatment copper concentration (2.58 µg/L) was subtracted from each of the measured concentrations prior to calculation of the daily copper load leaving the reservoir. This indicates that only 38 lbs of the 113 lbs (34%) leaving the reservoir may be attributed to copper sulfate application. The 38 lbs represents 2% of the total mass (5,000 lbs) applied to the reservoir on June 23.

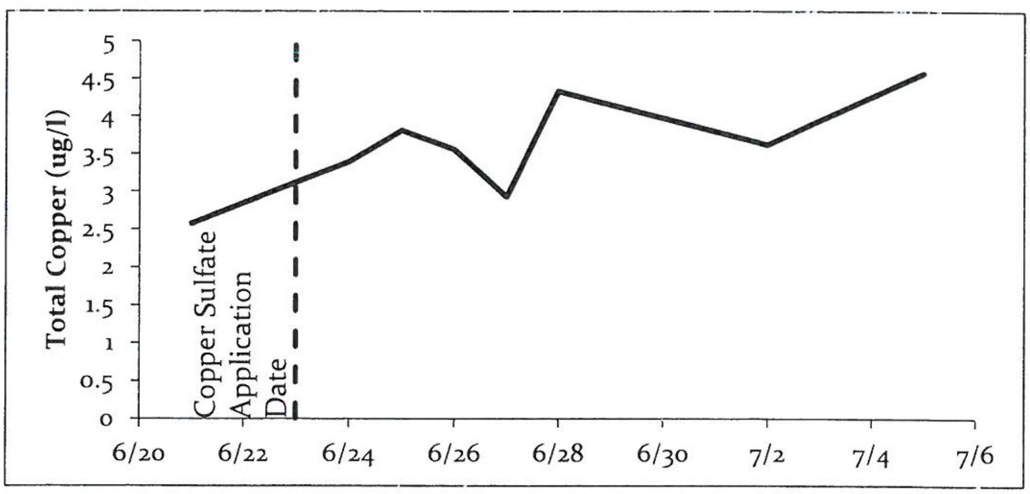

Figure 1. Total Copper Concentrations in the Wachusett Reservoir Intake after Copper Sulfate Application on June 23, 1995

Table 2. Wachusett Reservoir Copper Sulfate Applications: 1995 - 2012

Date	Algal Species	$CuSO_4$ (lbs)	Copper Ion (lbs)	Target Concentration (mg/l)	Depth (Surface/Deep)
6/23/1995	*Anabaena*	5,000	1,250	0.15	S
8/6/1996	*Anabaena*	5,000	1,250	0.15	S
8/9/1996	*Synura*	5,000	1,250	0.15	S
8/13/1996	*Synura*	5,000	1,250	0.15	S
6/22/1997	*Anabaena*	5,000	1,250	0.15	S
8/20/1997	*Synura*	5,000	1,250	0.15	D
6/19/1998	*Chrysosphaerella, Dinobryon*	5,000	1,250	0.15	S
7/10/1998	*Anabaena*	5,000	1,250	0.15	S
1/14/1999	*Diatoms*	1,750	438	0.05	S
6/15/1999	*Anabaena*	5,000	1,250	0.15	S
8/24/1999	*Synura, Uroglena*	5,000	1,250	0.15	D
7/7/2000	*Chrysosphaerella, Dinobryon*	5,000	1,250	0.15	D
6/8/2001	*Anabaena*	5,000	1,250	0.15	S
9/6/2001	*Synura*	5,000	1,250	0.15	D
6/20/2002	*Anabaena*	5,000	1,250	0.15	S
8/15/2002	*Anabaena*	5,000	1,250	0.15	S
8/22 - 8/24/2002	*Synura*	5,000	1,250	0.15	D
6/25/2003	*Anabaena*	5,000	1,250	0.15	S
7/7/2004	*Chrysosphaerella*	5,000	1,250	0.15	D
7/12/2004	*Chrysosphaerella*	5,000	1,250	0.15	D
7/20/2004	*Chrysosphaerella*	2,500	625	0.07	D
7/29/2004	*Anabaena, Chrysosphaerella*	5,000	1,250	0.15	S, D
7/30/2004	*Anabaena*	3,750	938	0.11	S
8/6/2004	*Chrysosphaerella*	3,750	938	0.11	D
8/12/2004	*Chrysosphaerella*	2,500	625	0.07	D
6/5/2005	*Synura*	5,000	1,250	0.15	D
6/21/2005	*Anabaena*	5,000	1,250	0.15	S
7/22/2005	*Chrysosphaerella*	5,000	1,250	0.15	D
7/26/2005	*Chrysosphaerella*	5,000	1,250	0.15	D
8/2/2005	*Chrysosphaerella*	5,000	1,250	0.15	D
8/20/2005	*Chrysosphaerella*	5,000	1,250	0.15	D
6/17/2006	*Anabaena*	5,000	1,250	0.15	S
8/15/2010	*Dinobryon*	5,000	1,250	0.15	D
7/29/2011	*Dinobryon*	5,000	1,250	0.15	D
8/7/2011	*Dinobryon*	5,000	1,250	0.15	D
8/12/2011	*Dinobryon*	5,000	1,250	0.15	D
9/2/2011	*Dinobryon, Synura*	5,000	1,250	0.15	D
6/19/2012	*Chrysosphaerella*	5,000	1,250	0.15	D
7/6/2012	*Chrysosphaerella*	5,000	1,250	0.15	D
7/16/2012	*Chrysosphaerella*	5,000	1,250	0.15	D
7/25/2012	*Chrysosphaerella*	5,000	1,250	0.15	D

In 2001 MWRA again implemented a monitoring program to measure the impact of copper sulfate on copper concentrations within the reservoir and its ultimate contribution to copper levels in the Clinton wastewater treatment plant. Two copper sulfate applications occurred during the study period in June (surface) and September (deep). In June, no elevated copper concentrations above the low baseline copper concentrations observed in Wachusett appeared. In September, deep samples showed an increase in copper concentration to 60 µg/L (Figure 2); surface samples did not show significant increases in copper concentration. MWRA concluded that "based on the results of this study, [copper sulfate] reservoir treatment made only a brief and minimal contribution to the Clinton wastewater treatment plant influent loads."

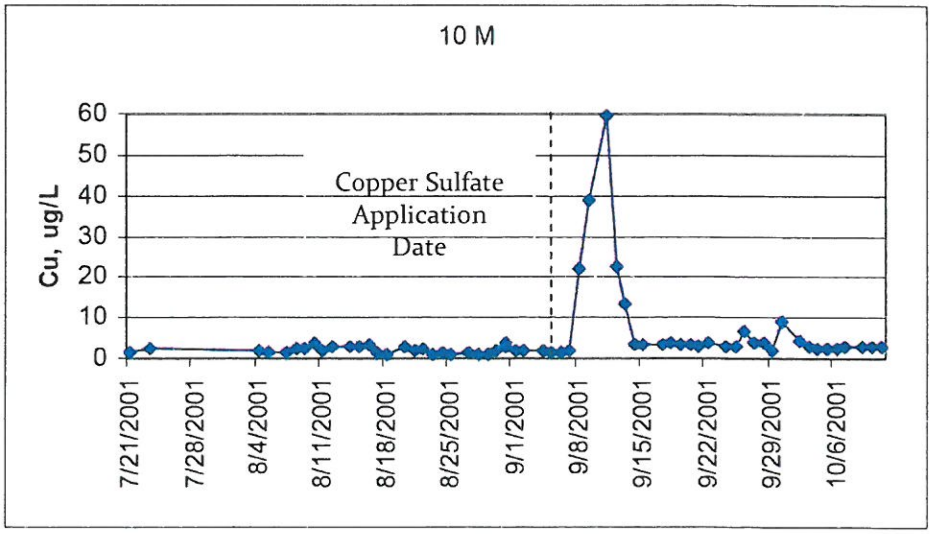

Figure 2. Copper Concentration Measured in the Copper Sulfate Application Area, 2001 Copper Fate and Transport Study. Copper Sulfate Applied on September 6, 2001 (MWRA, 2011)

In July 1995, sediment samples were collected to assess whether copper has accumulated in sediments as a result of copper sulfate applications. The survey consisted of samples in the treatment area and background locations; background locations were selected in areas that had not been treated with copper sulfate that were at depths similar to those of the treatment area sampling locations.

Sediment copper levels recorded in the 1995 program varied from 24 to 74 mg/kg. Concentrations were lowest on average (around 40 mg/kg) in samples collected from the area that receives the majority of copper sulfate applications. Background levels (around 50 mg/kg) were slightly higher than the treatment area samples, although the highest concentrations found in 1995 (around 70 mg/kg) were found within the treatment area. Based on the results of the 1993 and 1995 sediment copper sample results, it does not appear that copper sulfate applications increase copper levels in the sediments when compared with sediment copper concentrations in non-application or areas adjacent to the application area of the reservoir.

Lake Cochichewick

Lake Cochichewick in North Andover, Massachusetts is a 575-acre, elongate reservoir with an approximate water volume of 15,000 ac-ft. The intake is located at the southern end near the bottom in 18 feet of water. This lake was treated for control of cyanobacteria, mainly *Anabaena, Aphanizomenon* and *Microcystis*, in 1988-1991, 1993, 2000-2007, 2009, and 2012. Watershed management actions have helped reduce problems in some years, but years with elevated spring runoff and particularly warm summers still promote cyanobacteria blooms. In-lake inactivation of phosphorus has not been attempted, and may provide additional relief, but more work on watershed issues is perceived to be necessary before an in-lake phosphorus inactivation investment is deemed cost-effective. Consequently, algaecide treatments have been conducted in 15 out of the last 25 years.

Treatments have been conducted by a contract applicator, Aquatic Control Technology from Sutton, MA. Treatments involve application of 3,500 lbs of copper sulfate to the southern half of the lake in August of most treatment years. This yields a dose of 0.04 mg/L as copper in the southern half of the lake to the depth of the thermocline (18-20 feet). Assuming initial mixing to about 10 ft, a concentration of 0.07 mg/L as copper would be achieved in the upper waters, where cyanobacteria are most abundant. The maximum average copper level in the target area is estimated at 0.09 mg/L as copper, although instantaneous levels would be higher at the point of application right at the surface of the reservoir.

The target cyanobacteria are buoyant and tend to concentrate in upper waters, although they can be found at any depth and wind can mix them to the depth of the thermocline. Treating at the surface provides the largest concentration of copper in the water volume where the target algae are likely to be most abundant, with increasing dilution as the applied copper mixes and settles, but maintaining a potentially lethal dose down to the target depth of 18-20 ft.

Algae are considered to be controlled throughout the entire reservoir for at least a month and usually through the growing season in response to a single treatment. In just two years out of 15 treatment years was a second treatment necessary. It is not known if the copper is moving horizontally toward the northern end to kill algae outside the treatment zone, or if "control" is declared as a function of low algae in the intake, in which case algae in the northern area that do not reach the intake before the bloom dies out are simply not being assessed.

References

CDM (2006). Understanding Algal Dynamics in Wachusett Reservoir to Manage Taste and Odor. *Wachusett Reservoir Water Treatment Plan EIR/Conceptual* Design. Prepared for the Massachusetts Water Resources Authority.

Massachusetts Water Resources Authority [MWRA] (2011). Algae Monitoring and Control Program.

SECTION 4: Pest Management Options Evaluation

(See Attached Report)

Alternatives Analysis

Introduction

Lake Auburn is the principal drinking water supply for the communities of Lewiston and Auburn, Maine. Historically, Lake Auburn has been known for its excellent water quality, and the Auburn Water District and Lewiston Water Division (AWD/LWD) were granted a filtration waiver for Lake Auburn from Maine Division of Environmental Health in 1991. Lake Auburn's excellent water quality results from its largely undeveloped watershed and the strong watershed protection program implemented by the utilities. The ongoing work to protect the watershed and the lake to maintain the filtration waiver has resulted in significant cost savings to AWD/LWD over the years.

In late summer/fall 2012, water quality in Lake Auburn was degraded due to a combination of factors that raised turbidity in the lake close to the limit allowed under the filtration avoidance waiver granted to AWD/LWD. Dissolved oxygen (DO) was severely reduced throughout the bottom waters of the lake (DO was <2 mg/L) creating anoxic conditions, compromising the cold water fishery habitat, and resulting in the death of some lake trout (Togue). Following the fish kill, Maine's Department of Inland Fisheries and Wildlife conducted a survey where they netted and identified the fish and found that some of the lake trout survived.

Need for Algicide Treatment

While the causal relationships in water quality are not completely known, it is clear that if the lake's water quality continues to degrade it would put AWD/LWD at risk for violation of the compliance parameters for filtration avoidance waiver, and thus, could require the need for more advanced water treatment facilities. The increase in late summer/early fall algal blooms caused the increase in turbidity, which is one of the compliance parameters for maintaining the filtration waiver. This compliance criterion requires that turbidity at the point of withdrawal at Lake Auburn must not exceed 5 NTU for more than two events per year and not more than 5 events in ten years. The primary agency may waive an exceedance (a 'turbidity event') if they determine that the event or the circumstances leading to the event exceeding 5 NTU are unusual and unpredictable. If the turbidity levels are exceeded and not waived, filtration would be required to be added to the existing water treatment plant.

The Lake Auburn Watershed Protection Commission (LAWPC), along with CDM Smith Inc., Comprehensive Environmental, Inc., and Dr. Ken Wagner of Water Resources Services Inc., wrote a report describing causes of recent degradation in water quality and recommending short-term and long-term management options to mitigate the adverse impacts of excess phosphorus on the water quality of Lake Auburn (CDM Smith, 2013). This report concluded that the relative high levels of turbidity experienced in Lake Auburn in 2011 and 2012 were most likely attributed to blooms of blue-green algae. Data from Bates College show that the alga *Anabaena* was the dominant species in the lake during periods of high turbidity, although relative high cell counts of *Microcystis* and *Gomphosphaeria* were also identified. The first two of these blue-green algae can produce nuisance taste and odors. While there are no long-term records of algal levels in the lake, historical Secchi depth and turbidity data indicate that blooms of the magnitude and duration of the 2011 and 2012 blooms seem to be unprecedented.

In response to this change in water quality in the lake, AWD/LWD are investigating immediate, short-, and long-term actions that can be implemented to improve lake water quality. The application of algicide to the lake is a short-term measure that would allow AWD/LWD to respond quickly to an emerging bloom on the lake (should one emerge in 2013 or beyond) while implementing long-term measures to reverse the degradation of water quality. A plan for applying algicide to Lake Auburn is included as a separate document; this alternatives analysis discusses other short- and long-term lake management options being considered by AWD/LWD that would reverse the degradation of water quality.

Regulatory Requirements

This document addresses the regulatory requirement for an alternatives analysis prior to receiving a permit to apply algicide. To apply algicide to a body of water in the state of Maine, AWD/LWD must complete two application documents:

1. General Application for Waste Discharge License (WDL)/ Maine Pollutant Discharge Elimination System (MEPDES) Permit; and

2. Discharge of Pesticide(s) To Treat A Public Water Supply Supplemental Application Form.

The MEPDES application requires an alternatives analysis to assess options to the proposed use of algicide. The options considered should include the following categories:

- no action,
- prevention,
- mechanical/physical methods,
- cultural methods,
- biological control agents, and
- algicides.

Each of the options was assessed with respect to engineering, cost, impact to water quality, impact to non-target organisms, and feasibility.

Initial Screening of Alternatives

A wide range of short- and long-term management approaches exist to reduce algal blooms and increase dissolved oxygen concentrations in water supply lakes and reservoirs. In Lake Auburn, management approaches were evaluated with respect to their ability to prevent algal blooms and high turbidity and to protect the cold water fishery. These management approaches can be divided into four broad categories: prevention, in-lake mechanical/physical methods, cultural methods, and algicides. An initial analysis of these management options screened for feasibility and applicability to Lake Auburn. Table 1 provides a more in-depth discussion of the mode of action, advantages, disadvantages, and applicability of each management approach considered in this study.

Table 1. Initial Screening of Alternatives

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO LAKE AUBURN
PREVENTION				
1) Watershed Management	♦ Includes wide range of watershed and lake edge activities intended to eliminate nutrient sources or reduce delivery to lake ♦ Essential component of algal control strategy where internal recycling is not the dominant nutrient source, and desired even where internal recycling is important	♦ Acts against the original source of algal nutrition ♦ Creates sustainable limitation on algal growth ♦ May control delivery of other unwanted pollutants to lake ♦ Facilitates ecosystem management approach which considers more than just algal control	♦ May involve considerable lag time before improvement observed ♦ May not be sufficient to achieve goals without some form of in-lake management ♦ Reduction of overall system fertility may impact fisheries ♦ May cause shift in nutrient ratios to favor less desirable algae	♦ Applicable, but not as a short-term measure to control algae and thus limit potential high turbidity to avoid violating the terms of the filtration waiver. Watershed management is a required part of comprehensive plan to reduce nutrient concentrations in the lake.
IN-LAKE MECHANICAL/PHYSICAL CONTROLS				
2) Circulation and destratification	♦ Use of water or air to keep water in motion ♦ Intended to prevent or break stratification ♦ Generally driven by mechanical or pneumatic force	♦ Reduces surface build-up of algal scums ♦ May disrupt growth of blue-green algae ♦ Counteraction of anoxia improves habitat for fish/invertebrates ♦ Can eliminate localized problems without obvious impact on whole lake	♦ May spread localized impacts ♦ May lower oxygen levels in shallow water	♦ Not applicable. Although circulation would reduce or eliminate internal loading of phosphorus from sediments, it would disturb the cold water fishery, reducing habitat for lake trout.

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO LAKE AUBURN
3) Drawdown	♦ Lowering of water over autumn period allows oxidation, desiccation and compaction of sediments ♦ Duration of exposure and degree of dewatering of exposed areas are important ♦ Algae are affected mainly by reduction in available nutrients.	♦ May reduce available nutrients or nutrient ratios, affecting algal biomass and composition ♦ Opportunity for shoreline clean-up/structure repair ♦ Flood control utility ♦ May provide rooted plant control as well	♦ Possible impacts on non-target resources ♦ Possible impairment of water supply ♦ Alteration of downstream flows and winter water level ♦ May result in greater nutrient availability if flushing inadequate	♦ Not applicable. The water surface elevation in Lake Auburn cannot be lowered enough to achieve these benefits. Furthermore, before managed releases could occur measures to retain salmon in the lake would need to be implemented.

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO LAKE AUBURN
4) Dredging	♦ Sediment is physically removed using suction or cutterhead dredges ♦ Dredges create a slurry that is hydraulically pumped to containment area and dewatered. Sediment is retained; water is discharged. ♦ Nutrient reserves are removed and algal growth can be limited by nutrient availability	♦ Can control algae if internal recycling is main nutrient source ♦ Can reduce sediment oxygen demand ♦ Can improve spawning habitat for many fish species ♦ Allows complete renovation of aquatic ecosystem ♦ Possible mechanism to control *Gloeotrichia* cysts	♦ Often leaves some sediment behind ♦ Temporarily removes benthic invertebrates ♦ Interference with recreation or other uses during dredging ♦ Can result in short term elevated turbidity levels	♦ Applicable but costly compared other approaches. Control of sediment phosphorus would require dredging in 9 to 15 m of water. Dredging to control *Gloeotrichia* would require dredging of shallow sediments down to either 4.6 or 13 m. Further investigation on *Gloeotrichia* recruitment areas would be needed before dredging would be recommended. In both cases, dredging would be truly restorative.
5) Selective withdrawal from the water intake	♦ Discharge of bottom water which may contain (or be susceptible to) low oxygen and higher nutrient levels ♦ May be pumped or utilize passive head differential	♦ Removes targeted water from lake efficiently ♦ May prevent anoxia and phosphorus build up in bottom water ♦ May remove initial phase of algal blooms which start in deep water	♦ May promote mixing of remaining poor quality bottom water with surface waters ♦ May cause unintended drawdown if inflows do not match withdrawal	♦ Potentially applicable but not in the short term; raw water intake was recently extended 900 ft. and cannot be modified for a hypolimnetic withdrawal. This alternative would require construction of a new longer intake.

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO LAKE AUBURN
6) Hypolimnetic aeration or oxygenation	♦ Addition of air or oxygen provides oxic conditions ♦ Maintains stratification ♦ Can also withdraw water, oxygenate, then replace	♦ Oxic conditions reduce P availability ♦ Oxygen improves habitat ♦ Oxygen reduces build-up of reduced compounds	♦ May disrupt thermal layers important to fish community ♦ Theoretically promotes supersaturation with gases harmful to fish	♦ Applicable. Would prevent anoxic conditions from occurring, reducing phosphorus release rate from sediments and protecting the cold water fishery.
7) Phosphorus inactivation	♦ Typically salts of aluminum, iron or calcium are added to the lake, as liquid or powder ♦ Phosphorus in the treated water column is complexed and settled to the bottom of the lake ♦ Phosphorus in upper sediment layer is complexed, reducing release from sediment ♦ Permanence of binding varies by binder in relation to redox potential and pH	♦ Can provide a decrease in phosphorus concentration in water column ♦ Can minimize release of phosphorus from sediment ♦ May remove other nutrients and contaminants as well as phosphorus ♦ Flexible with regard to depth of application and speed of improvement	♦ Possible toxicity especially by aluminum ♦ Possible release of phosphorus under anoxia or extreme pH ♦ May cause fluctuations in water chemistry, especially pH, during treatment ♦ Possible resuspension of floc in shallow areas ♦ Adds to bottom sediment	♦ Applicable; internal load is a major source of phosphorus and inactivation with aluminum is possible. Requires more local data to implement, so cannot be used as a short term mitigation technique.

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO LAKE AUBURN
8) Dilution and flushing	♦ Addition of water can dilute nutrients and flush system to minimize algal buildup ♦ Can occur continuously or periodically	♦ Dilution reduces nutrient concentrations without altering load ♦ Flushing minimizes detention so the response to pollutants may be reduced	♦ Diverts water from other uses ♦ Flushing may wash desirable zooplankton from lake ♦ If water used is of poorer quality nutrient loads can increase	♦ Not applicable. Although groundwater resources could be used to enhance dilution and flushing, they have not been quantified and if taken from within the basin would ultimately reduce baseflow in tributary streams.
ALGICIDE				
9) Algicides	♦ Liquid or pelletized algicides applied to target area ♦ Algae killed by direct toxicity or metabolic interference ♦ Typically requires application at least once/yr, often more frequently	♦ Rapid elimination of algae from water column , normally with increased water clarity ♦ May result in net movement of nutrients to bottom of lake	♦ Possible toxicity to non-target species ♦ Restrictions on water use for varying time after treatment ♦ Increased oxygen demand and possible toxicity ♦ Possible recycling of nutrients	♦ Applicable. Can be applied as a temporary stopgap measure until more permanent measures can be implemented. Most effective when applied prior to the exponential growth phase.

OPTION	MODE OF ACTION	ADVANTAGES	DISADVANTAGES	APPLICABILITY TO LAKE AUBURN
9a) Copper sulfate	♦ Cellular toxicant, disruption of membrane transport ♦ Applied as wide variety of liquid or granular formulations	♦ Effective and rapid control of many algae species ♦ Approved for use in most water supplies	♦ Possible toxicity to aquatic fauna ♦ Accumulation of copper in system ♦ Resistance by certain green and blue-green nuisance species ♦ Lysing of cells releases nutrients and toxins	♦ Applicable; requires a permit from Maine DEP. This is the recommended form of algicide for application to Lake Auburn.
9b) Peroxides	♦ Disrupts most cellular functions, tends to attack membranes ♦ Applied as a liquid or solid. ♦ Typically requires application at least once/yr, often more frequently	♦ Rapid action ♦ Oxidizes cell contents, may limit oxygen demand and toxicity	♦ Much more expensive than copper ♦ Limited track record ♦ Possible recycling of nutrients	♦ Applicable. Less disruptive than copper, but more expensive. Tends to work best on cyanobacteria, but unlikely to prevent all blooms in fertile system. This form of algicide is not recommended for Lake Auburn.
CULTURAL CONTROLS				
10) Enhanced grazing	♦ Manipulation of biological components of system to achieve grazing control over algae ♦ Typically involves alteration of fish community to promote growth of grazing zooplankton	♦ May increase water clarity by changes in algal biomass or cell size without reduction of nutrient levels ♦ Can convert unwanted algae into fish ♦ Harnesses natural processes	♦ May involve introduction of exotic species ♦ Effects may not be controllable or lasting ♦ May foster shifts in algal composition to even less desirable forms	♦ Potentially applicable, but the addition of fish may have detrimental trophic effects on the existing fish population. Minimal information available on current grazing capacity.

A list of management options considered and whether or not the management option is applicable to Lake Auburn is presented in Table 2.

Table 2. Applicability of Management Options to Lake Auburn

Alternative	Feasibility/Applicability
Watershed management	Applicable
Circulation and destratification	Not Applicable
Drawdown	Not Applicable
Dredging	Applicable
Selective withdrawal	Potentially applicable
Hypolimnetic aeration or oxygenation	Applicable
Phosphorus inactivation	Applicable
Dilution and flushing	Not applicable
Algicides	Applicable
Enhanced grazing	Potentially applicable

As described in Table 2, the screening-level analysis of lake management approaches determined that the most viable options are watershed management (prevention), dredging (mechanical/physical methods), aeration (mechanical/physical methods), phosphorus inactivation (mechanical/physical methods), and algicide.

Alternatives Analysis

Lake management approaches identified as feasible and applicable according to the initial screening assessment of alternatives described above and in Table 2 were further assessed with respect to engineering, cost, impact to water quality, and impact to non-target organisms. This section describes each of these options and compares them against the no action alternative and the proposed algicide application plan.

No Action

Background on Approaches and Impacts

The no action alternative consists of maintaining the status quo. No additional actions will be taken to control phosphorus loads from the watershed nor will short- or long-term in-lake control measures be implemented.

Although the no action alternative may not result in poor lake water quality in 2013, it is not a viable option for Lake Auburn. The consequences of having another algal bloom and the associated increases in turbidity are high because this may cause AWD/LWD to lose its filtration waiver and be required to build additional treatment facilities. Therefore, the no action alternative is not recommended; at a minimum a short-term contingency plan, such as the algicide application plan presented here, must be put into place to control an algae bloom should one occur in 2013 or beyond.

The criteria used to assess the no action alternative are described below.

Impact to Water Quality

The drivers behind the recent degradation in water quality in Lake Auburn are not well defined and additional data collection is needed. These data are being collected in 2013 to better understand the drivers that may have caused this water quality degradation. In 2012 water quality became so degraded that an algae bloom occurred, causing high turbidity and a large oxygen demand, ultimately compromising the cold water fishery and causing a fish kill. Although the available data do not allow us to predict what water quality conditions will be in 2013 and beyond, under the correct conditions it is possible, and even likely, that these conditions could occur again.

Impact to Non-Target Organisms

Again, because the causes of the recent degradation in Lake Auburn water quality are not clear, it is not possible to accurately predict the impacts of taking no action on non-target organisms. If an algal bloom occurs in 2013 or beyond resulting in basin-wide anoxia, the cold water fishery will again be threatened, and another fish kill may occur.

Cost Effectiveness

This is a low cost option as no action is taken. However, if turbidity exceeds 5 NTU and the filtration waiver is voided, then an expensive upgrade to the water treatment plant would be required. However, even if a filtration plant is built, AWD/LWD will still need to maintain the watershed; at a minimum AWD/LWD will need to invest in additional watershed controls.

Prevention – Additional Watershed Controls

Background on Approaches and Impacts

Watershed controls are ultimately the best way to control phosphorus loading to the lake and algal growth. However, they require significant time for the beneficial effects on the lake to take root. In addition, the Lake Auburn watershed encompasses five towns (Auburn, Buckfield, Hebron, Minot, and Turner) and is mostly privately owned. As a result, AWD/LWD partially need to rely on outside parties, which may limit the overall nutrient reduction that can be achieved using watershed controls alone. Nutrient loads from nonpoint sources such as roads, residential development, agricultural activity, and commercial activity, comprise a large fraction of the total watershed load if uncontrolled. Lake Auburn is already well controlled, and the Lake Auburn Watershed Protection Commission (LAWPC) has numerous stringent watershed controls already in place. Nonetheless, additional watershed controls are necessary to continue to protect Lake Auburn's water quality.

Lake Auburn does not have any point source discharges, so nutrient loads from nonpoint sources are the only external input of phosphorus into Lake Auburn. As part of Phase 1 of the water quality study for Lake Auburn, Comprehensive Environmental Inc. (CEI) (Appendix A in CDM Smith, 2013) performed a comprehensive survey of the watershed to identify potential 'hot-spot' areas that may contribute high loads of sediment and nutrients to Lake Auburn.

CEI is currently performing Phase 2 of this study to identify additional viable and effective watershed controls; it is anticipated that these measures could consist of nonpoint source controls or structural stormwater controls. Nonpoint source controls may involve changes to agricultural and forestry management practices and the addition of additional regulations to further strengthen lake protection and reduce the likelihood of nutrient runoff into the lake. Structural stormwater controls may include dredging of the Basin to improve stormwater retention, creation of additional stormwater detention and treatment ponds, and diversion of runoff from major roads into stormwater treatment structures.

AWD/LWD collectively have a strong history of implementing watershed controls. The Lake Auburn Watershed Protection Commission was founded in 1993 to protect this valuable drinking water resource; since then the Commission has applied a Multiple Barrier Approach to ensure clean drinking water for the citizens of Lewiston and Auburn. As a result, the political and operational requirements for a successful watershed control program are already in place. In addition, the LAWPC owns a substantial amount of land that is directly tributary to the lake, and the watershed is largely forested. This means there is ample space to build structural stormwater controls (CEI, 2010). Furthermore, the small size of the watershed makes it relatively easy to identify and implement practices to reduce the overall nonpoint source load without the political and logistical challenges of a larger, more urban contributing watershed.

Watershed controls are very applicable to Lake Auburn because

- The watershed is the long-term source of phosphorus to the lake,
- Any inputs of phosphorus that do not reach the lake through implementation of watershed actions protects water quality, and some measures can be very cost effective,
- an overall reduction of phosphorus availability in the lake is the only feasible way to sustainably reduce algal blooms in the long term, and watershed management is an important part of that effort; and
- the existence of the LAWPC supports the framework for implementation of more stringent watershed controls and building and maintaining nonpoint source pollutant trapping infrastructure.

Watershed controls are an applicable, feasible method to achieve long-term control of phosphorus in the Lake Auburn watershed. However, additional watershed controls will not have a significant impact on Lake Auburn water quality in the short-term; therefore, this method cannot be used to avoid a potential algal bloom in 2013. The substantial expected benefits to long-term water quality realized by watershed control indicates that these controls should be implemented in parallel with other short- and long-term control measures in order to maintain Lake Auburn as a high quality drinking water source.

The criteria used to assess watershed controls are discussed below.

Impact to Water Quality

Implementation of watershed controls to reduce nonpoint source phosphorus contributions will not have an immediate effect on water quality in Lake Auburn because the lake has a long detention time (over 4 years) and a substantial mass of sediment phosphorus that can be released under anoxic conditions. Over time, however, the reduced phosphorus load from the watershed could yield a substantial increase in overall water quality.

Impact to Non-Target Organisms

Watershed controls should only have a beneficial impact to non-target organisms in Lake Auburn. In addition to a reduction in algal growth, nonpoint source reduction and watershed controls will reduce the influent concentration of other harmful pollutants. This is an overall net positive benefit for non-target organisms, providing better water quality for aquatic life while reducing the algae population naturally.

Cost Effectiveness

Watershed controls vary in cost and range from low cost options, such as regulatory controls, to high cost options, such as large structural stormwater controls. Although capital costs can be high for large scale stormwater control infrastructure, these projects will reduce the need for short-term interim in-lake mitigation techniques in the future.

The cost effectiveness of watershed controls for Lake Auburn cannot be specified at this time because the plan is currently being developed. Below we provide some general information on the cost of watershed controls.

Published cost estimates for phosphorus removal using watershed controls vary considerably. A recent and as-yet unpublished study by DeBusk and Hunt (2012) itemized nonpoint source controls for water supply watersheds necessary to meet water quality standards, and provided costs per pound of total phosphorus removed that included street sweeping at $4,500 to $9,000, simple wetland detention systems at $18,000 to $36,000, more elaborate bioretention systems at $45,000 to $230,000, and permeable pavement at $270,000. CDM Smith experience in other locations provides additional cost estimates including: dry or wet detention basins range from $200 – $2,800 per pound of total phosphorus removed, vegetated swales $35 – $50 per pound of total phosphorus removed, and rain gardens $1,000 – $8,715 per pound of phosphorus removed. CEI's 2010 watershed report, which is being updated as part of the current effort, provided a phosphorus removal goal for Lake Auburn is 1,034 pounds per year (CEI, 2010). Total costs for implementing watershed controls for Lake Auburn would depend on the number and type of controls needed, and verification of the target amount of phosphorus to be controlled. An initial cost estimate by CEI indicated that watershed controls for phosphorus will cost around $2 million. Phase 2 of the water quality study will investigate and recommend specific watershed controls that will reduce phosphorus load into Lake Auburn.

In-Lake Physical Controls – Dredging

Background on Approaches and Impacts

Dredging physically removes sediment from the lake bottom. Although there are several different ways to dredge a lake, the only option applicable to large lakes like Lake Auburn is hydraulic removal; other methods involve lowering the lake level, which is not feasible for such a large lake. Hydraulic removal involves using suction or cutterhead dredges to create a slurry (mixture of water and sediment) that can be hydraulically pumped out of the lake. The slurry is typically dewatered, the water is returned to the lake, and the sediment is discarded.

Dredging of Lake Auburn consists of two alternatives that may be applied singularly or in concert with one another. The first alternative involves a deep dredging operation to remove sediment high in iron-bound phosphorus; this would occur in water deeper than about 9 m (30 ft). The second alternative involves dredging shallow water to remove *Gloeotrichia* cysts resting on the benthos prior to recruitment; this would occur in water <9 m deep, with a focus on areas less than 4.6 m (15 ft) deep based on expected relative contribution of *Gloeotrichia* from depth contours based on light penetration.

Although expensive and invasive, dredging is a very effective lake management tool for both removing sediment phosphorus and *Gloeotrichia* cysts prior to recruitment into the water column. It can be truly restorative, allowing complete renovation of the aquatic ecosystem by physically removing the source of internal phosphorus load or the majority of the *Gloeotrichia* population. It can also reduce sediment oxygen demand, if all soft sediment is removed, further reducing the likelihood that anoxic conditions will develop.

Dredging in Lake Auburn is technically feasible. The sediment to be removed is likely uncontaminated, so disposal costs would be reduced compared with the cost associated with handling contaminated sediments. In addition, the shallow treatment area specified is well within the limits of available technology. However, despite the many benefits, dredging is not a viable method for controlling sediment phosphorus or *Gloeotrichia* in Lake Auburn because the costs for deep dredging (sediment phosphorus removal) or shallow dredging (*Gloeotrichia* removal) are extremely high. Therefore dredging is not a realistic option for Lake Auburn, and is not a recommended lake management approach.

The criteria used to assess the applicability of dredging to Lake Auburn are discussed below.

Impact to Water Quality

Dredging could have a net positive impact on water quality for both the deep and shallow alternatives. Although induced turbidity is minimal with hydraulic removal, it is possible that turbidity could be temporarily elevated during dredging operations.

The deep dredging alternative removes nutrient reserves from the sediments. This reduces the source of internal phosphorus load to the lake, which may result in an immediate decrease in phosphorus release rate during periods of anoxia.

The shallow dredging alternative removes *Gloeotrichia* cysts from the sediment-water interface. The removal of the *Gloeotrichia* cysts should significantly reduce or eliminate the peak *Gloeotrichia* concentration during the growing season following dredging operations.

Impact to Non-Target Organisms

Impacts to biota, especially benthic invertebrates, are likely during dredging operations. A survey of benthic invertebrates in Lake Auburn has not been conducted, and would be needed prior to dredging better understand potential impacts.

Three potential concerns for Lake Auburn could impact the allowable timing for dredging operations: presence of mussels, potential presence of the threatened spotted turtle, and fish reproduction. If mussels are found in the lake, it may be necessary to collect a portion of the population and re-introduce them in the lake following dredging operations. Maine Inland Fisheries and Wildlife's website (MEDIFW, 2013) on the endangered species program lists the spotted turtle (*Clemmys guttata*) as state threatened; protection of this species would need to be considered in planning the dredging operation. Regarding fish reproduction, the timing of dredging may be restricted to prevent removal of demersal eggs and/or minimize smothering of eggs present in non-dredged portions of the lake. Impacts will also occur to more abundant invertebrates, and while not ideal, these populations are typically characterized by fast reproduction rates so the population levels will not be depressed for a substantial amount of time.

On the other hand, dredging can increase and improve spawning habitat for many fish species and remove pollutant reserves from the sediment, improving overall aquatic habitat quality.

Cost Effectiveness

Dredging is an expensive management technique, especially for a project on the scale of Lake Auburn. While dredging may yield a complete restoration of the aquatic ecosystem, it is typically only cost effective for smaller projects that are more easily managed, or where dredging would provide major additional benefits, such as increased volume and supply capacity where it is currently inadequate. There are many costs associated with dredging: planning and permitting, operation of the dredge, and disposal of the dredged material. Dredging costs cannot be reliably estimated on a per unit volume basis, but an approximate estimate for the unit cost of hydraulic dredging (including disposal costs) in Lake Auburn is $30 per cubic yard of sediment removed.

The deep dredging operation to remove sediment with high iron-bound phosphorus concentration would need to remove sediment between 30 and 50 feet. This depth range is chosen because the shallowest depth of anoxia observed in 2012 was 9 meters (30 ft), and sediment iron-bound phosphorus measurements indicate that the peak concentrations occur around 15 meters (50 ft). Assuming that only the top 1.5 feet of sediment had to be removed, this corresponds to 2.1 million cubic yards of sediment, or $63.7 million at a unit cost of $30 per cubic yard.

The shallow dredging operation to remove sediment with *Gloeotrichia* cysts would need to remove sediment between 10 and 15 feet, which represents the expected zone from which most *Gloeotrichia* recruitment will occur. While *Gloeotrichia* is likely found in water shallower than 3 m (10 ft), these areas tend to be quite sandy and rocky, making dredging technically difficult, more expensive, and probably not necessary (viable resting stage density on sand and rock should be small). Again assuming that the top 1.5 feet of sediment is removed, this yields 3.9 million cubic yards of sediment or $117.9 million at a unit cost of $30 per cubic yard.

Both dredging operations have an exceptionally high cost, so they are not economically viable options for managing sediment phosphorus or the *Gloeotrichia* population in Lake Auburn.

Physical/Mechanical Controls – Hypolimnetic Oxygenation

Background on Approaches and Impacts

As an alternative for reducing algal bloom potential, hypolimnetic oxygenation is potentially applicable to Lake Auburn, but some additional study is needed to determine if this approach will control algal blooms in this case. As a means to improve hypolimnetic water quality, oxygenation is a very applicable method, but the drinking water supply intake is not in the hypolimnion, so no direct benefit will be accrued. A hypolimnetic oxygenation system would likely meet with regulatory approval, given that it would benefit water quality and habitat independent of any water supply benefits.

Hypolimnetic oxygenation is a technique for management of algae by introducing more oxygen into the water, intended to limit internal recycling of phosphorus, thereby controlling algae. Putting pure oxygen or air into the aquatic system increases oxygen concentration by transfer from gas to liquid, and generates a controllable mixing force. The oxygen transfer function is used to prevent anoxia in the bottom water layer, the hypolimnion. By keeping the hypolimnion from becoming anoxic during stratification, the release of phosphorus, iron, manganese and sulfides from deep bottom sediments is minimized and the build-up of undecomposed organic matter and oxygen-demanding compounds (e.g., ammonium) is decreased. Hypolimnetic oxygenation can also increase the volume of water suitable for habitation by zooplankton and fish, especially coldwater forms.

There are types of hypolimnetic oxygenation systems that are commonly applied to lakes similar to Lake Auburn. One type is a full lift hypolimnetic oxygenation approach that moves hypolimnetic water to the surface, aerates it, and replaces it in the hypolimnion. Bringing the water to the surface can be accomplished with electric, solar or wind-powered pumps, but is most often driven by pneumatic force (compressed air). Return flow to the hypolimnion is generally directed through a pipe to maintain separation of the newly oxygenated waters from the surrounding epilimnion. To provide adequate oxygen, the hypolimnetic volume should be pumped and oxygenated at least every month and preferably every two weeks.

Another hypolimnetic oxygenation system is the partial lift system, in which air is pumped into a submerged chamber in which exchange of oxygen is made with the deeper waters. The newly oxygenated waters are released back into the hypolimnion without destratification. A shoreline site for a housed compressor is needed, but the oxygenation unit itself is submerged and does not interfere with lake use or aesthetics.

An alternative approach involves a process called layer oxygenation. Water can be oxygenated by full or partial lift technology, but by combining water from different (but carefully chosen) temperature (and therefore density) regimes, stable oxygenated layers can be formed anywhere between the thermocline and the bottom of the lake. Each layer acts as a barrier to the passage of phosphorus, reduced metals and related contaminants from the layer below. Each layer is stable as a consequence of thermally mediated differences in density. The whole hypolimnion may be oxygenated, or any part thereof, to whatever oxygen level is deemed appropriate for the designated use.

The mechanism of phosphorus control exercised through hypolimnetic oxygenation is the maintenance of high oxygen and limitation of phosphorus release from sediments. To successfully oxygenate a hypolimnion, the continuous oxygen demand of the sediments must be met; this translates into a need to add enough oxygen and distribute it properly, neither of which is an easy task. It is also essential that an adequate supply of phosphorus binder, usually iron or calcium, be available to combine with phosphorus under oxic conditions. This is usually not an issue, but where longer term chemical reactions under anoxic conditions have limited binder availability, additional phosphorus binders may have to be added for oxygenation to have maximum effectiveness on phosphorus inactivation.

Technical feasibility considerations indicative of appropriate application of hypolimnetic oxygenation for reductions in nutrient concentrations and control of algae in lakes are listed below and are evaluated with regard to Lake Auburn:

- A substantial portion of the phosphorus load in 2011 and 2012 appears to have been associated with sediment sources within the lake, although further investigation may be needed before a conclusion can be drawn;

- studies have demonstrated that impact of internal loading on the lake is likely high, albeit uncertain at this time;

- external P load has been controlled to the maximum practical extent or is documented to be small as LAWPC has worked hard to limit nonpoint source inputs to Lake Auburn. However, recent investigation has suggested some areas of concern within the watershed and a complete evaluation of loading and relative contributions has not been completed at this time;

- hypolimnetic or sediment oxygen demand was likely high (>500 mg/m^2/day) in 2011 and 2012, albeit not in previous years;

- it appears very likely that adequate phosphorus inactivators are present for reaction upon addition of oxygen;

- shoreline space for a compressor or pump is available where access is sufficient and noise impacts will be small and power is available to run all machinery;

- the lake is bowl shaped, or at least not highly irregular in bathymetry (few separate basins and isolated coves);

- long-term application of the technique is accepted, although given the cost to run the system, it would not be preferable to operate the system every year. It may be a valid alternative to building an advanced treatment facility; and

- coldwater fishery habitat is abundant or an important goal.

No oxygenation could likely be conducted in 2013 as a consequence of necessary planning steps, required permitting processes, and cost. Data collection is underway and should be carefully coordinated to determine the efficacy of this approach as a possibility in 2014 or beyond, but hypolimnetic oxygenation would not be a valid short-term measure for maintaining compliance with the filtration waiver for use of Lake Auburn as a drinking water supply.

Impact to Water Quality

The success of oxygenation in controlling algae is largely linked to reducing available phosphorus. Short-term effectiveness may be achieved if oxygen levels near the bottom rise quickly and adequate phosphorus binders are present. Even then, a month or more of lag time might be expected for existing algae to suffer nutrient limitation or other stresses that reduce abundance. The control of phosphorus in surface waters may not be effective until the following year for hypolimnetic oxygenation.

Hypolimnetic oxygenation has been reported to be reasonably successful, but in many cases little improvement has been reported. Multiple factors may be responsible, one of which is continued metalimnetic anoxia, where organic particles accumulating near the thermocline create an anoxic layer above the oxygenated hypolimnion. An increase in transparency and reduction in blue-green algae were observed in a Connecticut lake using layer oxygenation within the thermocline of a eutrophic water supply lake. It was suggested that layer oxygenation (where the oxygenated water is used to create a stable layer instead of aerating the entire hypolimnion) can eliminate the problem of metalimnetic anoxia that allows rapid phosphorus recycle and can act as a barrier to fish migration.

Any oxygenation system can make a marked improvement in lake conditions, but it should be noted that practical experience has demonstrated that effects are not uniform or consistent within and among aquatic systems. Zones of minimal interaction will often occur, possibly resulting in localized anoxia and possible phosphorus release. Partial lift hypolimnetic oxygenation systems may allow a band of anoxic water to persist near the top of the metalimnion, allowing nutrient cycling and supply to the epilimnion and discouraging vertical migration by fish and zooplankton. Phosphorus binders must be available for oxygenation to facilitate phosphorus inactivation. Uniformity of results should be achievable with careful design and operation, but probably with increased cost.

Since oxygenation is an active treatment, the system must be kept running year after year, at least during the summer months. It seems plausible that effectiveness can be maintained over many years with this method, but there has been considerable variability in results. The Fresh Pond destratification system in Cambridge yielded positive results over a period approaching a decade, but has not performed as well in recent years. Notch Reservoir in North Adams also experienced improvement over about a decade with a hypolimnetic oxygenation system, but power failures allowed low oxygen zones to quickly develop at times. A long-term treatment of Lake Shenipsit, Connecticut with a layer oxygenation method revealed adequate oxygenation of the metalimnion in this 212 ha lake with compressor systems totaling 60 HP that delivered 240 CFM of air. Total phosphorus was reduced marginally while blue-green algae decreased and the algal community shifted to green algae and diatoms. The lake experienced a large increase in transparency after 2 years of layer oxygenation. The increase was associated with an increase in zooplankton, particularly *Daphnia*, which were assumed to be grazing on the algae and may have used the newly oxygenated zone as a daytime refuge from fish predation.

A number of successful cases of pure oxygen use have surfaced in recent years, all reporting much improved habitat but not all documenting algal changes. In many cases the watershed nutrient loads were not sufficiently controlled, and the oxygenation was supporting the fish community but not addressing the main sources of nutrients. Where internal recycling has been documented as the primary phosphorus source, these systems have been more effective at controlling algal blooms. The use of pure oxygen carries a higher material cost, but the lack of a power requirement in passive diffusion systems has offset the cost of oxygen.

Impact to Non-Target Species

There are very few negative impacts expected from hypolimnetic oxygenation, but algal blooms may not be controlled if other sources of phosphorus are available. Since oxygen levels are increased in previously anoxic areas, many organisms that require oxygen such as fish, aquatic insects and zooplankton are expected to increase.

The greatest short-term risk from hypolimnetic oxygenation is system failure after establishing an oxygenated zone. While cessation may not result in worse conditions than encountered before treatment, adjustment of system biota to a return to the low oxygen regime could be a problem. In several cases fish kills were reported in water supply reservoirs when oxygenation systems were shut off by power failures or mechanical difficulties.

Long-term impacts to biota such as zooplankton and fish may occur following any changes in algal abundance or species composition. Oxygen or nitrogen supersaturation could theoretically become a problem for fish in deep waters during oxygenation due to gas bubble disease, but formation of the right size bubbles from oxygenation is not expected. Gas bubble disease is most often a function of creation and entrapment of very fine air bubbles associated with hydropower facilities; oxygenation systems for drinking water reservoirs have not been observed to produce bubbles small enough to induce this disease. Nitrogen supersaturation represents a greater risk than oxygen levels, but no gas bubble disease has been detected in lakes with hypolimnetic oxygenation.

Cost Effectiveness

The cost of hypolimnetic oxygenation systems depends on the amount of oxygen to be delivered and how and where it is delivered. Based on the maximum extent of anoxia at the bottom of Lake Auburn (in 2012), about half the lake area could require oxygenation. The oxygen demand appears to be at the low end of the range where oxygenation is applied. The expected capital cost would therefore be in the range of $800 to $2000 per acre, or $1.0 million to $2.3 million. Operational costs for a pure oxygen diffusion system are anticipated to be on the order of $600 to $1200/day for up to 60 days, or $36,000 to $72,000 per year under the current conditions.

Physical/Mechanical Controls – Phosphorus Precipitation and Inactivation

Background on Approaches and Impacts

As an alternative for reducing algal bloom potential, phosphorus inactivation through an in-lake treatment is highly applicable to Lake Auburn, but no treatment could likely be conducted in 2013 as a consequence of necessary planning steps, required permitting processes, and cost. Regulatory acceptability of phosphorus inactivation appears positive in Maine, as this technique has been applied in other Maine lakes in the past.

Phosphorus can be inactivated in either the water column or within surficial sediments. Phosphorus precipitation by chemical complexing removes phosphorus from the water column and binds phosphorus in surficial sediments. This technique can control algal abundance until the phosphorus supply is replenished. Phosphorus inactivation that focuses on phosphorus precipitation from the water column is not very efficient at lower concentrations of phosphorus (<100 µg/L where aluminum is the binder, possibly lower where lanthanum is used), and is therefore not advantageous for many lake situations. It has greater applicability to stormwater management situations, usually through an injection system triggered by rain or increasing flows.

Phosphorus inactivation of surficial sediments aims to achieve long-term control of phosphorus release from lake sediments by adding enough phosphorus binder to the upper 4-10 cm of sediment to minimize releases, which are usually a function of dissociation from iron-based compounds under low oxygen conditions. This technique is most effective after nutrient loading from the watershed is sufficiently reduced, as it acts only on existing phosphorus reserves, not new ones added post-treatment. In-lake treatments are used when phosphorus budget studies of the lake indicate that the primary source of the phosphorus is internal (i.e., recycled from lake sediments).

Aluminum has been widely used for phosphorus inactivation, mostly as aluminum sulfate (alum) and often in combination with sodium aluminate (aluminate), as it binds phosphorus well under a wide range of conditions, including anoxia. Several other aluminum compounds have been less frequently applied and tend to be much more expensive. Lanthanum has more recently become commercially available for phosphorus inactivation, and may be preferable to aluminum where phosphorus stripping from the water column is the primary intent or where many sensitive organisms are present and toxicity is a large concern. Yet only a limited track record is currently available for lanthanum, with no treatments in New England as of yet. Furthermore, aluminum is the preferred compound for algae control.

Phosphorus inactivation is applicable as a long-term control measure for Lake Auburn.

- A substantial portion of the phosphorus load in 2011 and 2012 appears to have been associated with sediment sources within the lake, although further investigation may be needed before a conclusion can be drawn;
- studies have demonstrated the likely impact of internal loading on the lake (CDM Smith, 2013);
- external P load has been controlled to the maximum practical extent or is documented to be small as LAWPC has worked hard to limit nonpoint source inputs to Lake Auburn. However, recent investigation has suggested some areas of concern within the watershed and a complete evaluation of loading and relative contributions has not been completed at this time; and
- inactivation of phosphorus in the water column is expected to provide interim relief from algal blooms and turbidity while a prolonged watershed management program is conducted to reduce external loading.

Previous applications of aluminum in Maine have taken considerable planning, an effort not yet conducted for Lake Auburn, but it would appear that a properly justified and planned phosphorus inactivation project could be approved for Lake Auburn. Data collection is underway and should be carefully coordinated to determine the efficacy of this approach as a possibility in 2014 or beyond, but in-lake phosphorus inactivation would not be a valid short-term measure for maintaining compliance with the filtration waiver for use of Lake Auburn as a drinking water supply.

Impact to Water Quality

Commonly applied aluminum doses for sediment phosphorus inactivation range from about 5 to 50 g/m^2, with treatments up to 100 g/m^2 known from New England. Aluminum compounds are added to the water and colloidal aggregates of aluminum hydroxide are formed. These aggregates rapidly grow into a visible, brownish white floc, a precipitate that settles to the sediments over the following hours, carrying sorbed phosphorus and bits of organic and inorganic particulate matter in the floc. After the floc settles to the sediment surface, the water will usually be very clear. If enough alum is added, a layer of 1 to 2 inches of aluminum hydroxide floc will cover the sediments, mix with the upper few centimeters, and significantly retard the release of phosphorus into the water column as an internal load.

Nutrient inactivation has received increasing attention over the last decade as long lasting results have been demonstrated in multiple projects, including several in Maine. Where aluminum has not reduced algal densities, either the dose was inadequate or watershed sources were more important than internal loads. Furthermore, Lake Auburn is not well buffered so precautions would be needed to guard against pH shifts that would adversely affect water quality. Consequently, it is necessary to have a reliable assessment of the relative magnitude of loads and to know the proper aluminum dose. Planning for a phosphorus inactivation treatment requires substantial lead time.

There are numerous examples of successful aluminum treatment in lakes throughout New England. Annabessacook Lake in Maine suffered algal blooms for 40 years prior to the 1978 treatment with aluminum sulfate and sodium aluminate. A 65% decrease in internal phosphorus loading was achieved, blue-green algae blooms were eliminated, and conditions remained much improved for many years. Similarly impressive results have been obtained in Cochnewagon Lake in Maine. Kezar Lake in New Hampshire was treated with aluminum sulfate and sodium aluminate in 1984 after a wastewater treatment facility discharge was diverted from the lake. Both algal blooms and oxygen demand were depressed for several years, but began to rise more quickly than expected. Additional controls on external loads reversed this trend and conditions have remained markedly improved. No adverse impacts on fish or benthic fauna have been observed despite careful monitoring.

Aluminum sulfate and sodium aluminate were employed with great success at Lake Morey, Vermont. A pretreatment average spring total phosphorus concentration of 37 µg/L was reduced to 9 µg/L after treatment in late spring of 1987. Although epilimnetic phosphorus levels have varied since then, the pretreatment levels have not yet been approached. Oxygen levels increased below the epilimnion, with as much as 10 vertical feet of suitable trout habitat reclaimed. Some adverse effects of the treatment on benthic invertebrates and yellow perch were observed immediately after treatment (e.g., smothering of some invertebrates by the floc layer and poor growth by yellow perch for a season), but these proved to be transient phenomena and conditions have been acceptable and stable for over two decades.

Although some short-term effects have been noted, there do not seem to be any significant negative long-term impacts of phosphorus inactivation. Bioaccumulation of aluminum has not been reported. Reducing algal production might be expected to reduce fish production and increased transparency may allow macrophytes to increase and extend their depth distribution into deeper waters as sunlight penetration increases. However, no dissatisfaction with treatment results has been expressed in the studied cases, but it should be noted that use of aluminum may not appreciably reduce phosphorus levels in the water column. Lake Auburn phosphorus levels are <20 µg/L even during algal blooms, and aluminum would be very inefficient at reducing those levels further. A very high dose of aluminum may be needed (>10 mg/L), which would increase toxicity risk. Lanthanum may be more appropriate in this case, but no testing has been done and there are no similar examples for comparison.

Impact to Non-Target Organisms

Lake auburn contains important populations of salmonids (lake trout or Togue and salmon) and may harbor a wide array of benthic invertebrates, information on which is very limited. Additional studies would be needed to prepare for a possible treatment because the primary drawback to aluminum treatments is that reactive aluminum can be toxic to fish and invertebrates. The safe level of dissolved aluminum is considered to be about 50 µg/L. The amount of reactive aluminum is strongly influenced by pH and is very low between pH values of 6 and 8. A successful aluminum treatment must deliver enough aluminum to the surficial sediments to inactivate most of the iron-bound phosphorus present while keeping the reactive aluminum level in the water column at a low enough level to avoid toxicity, or keeping sensitive organisms out of the treatment area. Sediment testing of available phosphorus and lab assays for both the amount of aluminum needed and the effect of that aluminum dose on fish and invertebrates helps with treatment planning. Where the dose exceeds the toxicity threshold, the dose can be sequentially delivered in smaller amounts and a treatment pattern that minimizes exposure of sensitive organisms can be developed, but there may be some risk of toxicity.

Once reacted, the resultant aluminum compounds are non-toxic and rather stable. Short-term effects are therefore more likely than long-term impacts, and involve aluminum toxicity at low or high pH. In some cases dissolved aluminum concentrations have exceeded the safe level, but in most cases detectable fish and invertebrate kills have been avoided. In low alkalinity Kezar Lake, New Hampshire, dissolved aluminum concentrations were as high as 400 µg/L after application of alum and sodium aluminate, but no fish kills were observed. In Lake Morey, Vermont, dissolved aluminum reached concentrations as high as 200 µg/l in the epilimnion where the pH was near 8.0 SU. Despite the high aluminum concentrations, no direct fish mortality was observed. Losses of benthic invertebrates were reported in Lake Morey, but mainly from smothering under the aluminum floc. The eventual incorporation of the floc into the surficial sediments leads to transient impacts on benthic invertebrates.

Fish kills early in the use of aluminum in lakes resulted from lack of buffering. In these cases, the pH dropped to well below 6.0 SU and aluminum toxicity ensued. A fish kill was reported following aluminum sulfate and sodium aluminate addition to low alkalinity Hamblin Lake in Barnstable, Massachusetts in 1995 as a consequence of overbuffering and high pH (values as high as 9.3 SU), leading to aluminum toxicity and possibly pH shock. A kill similar to that at Hamblin Pond occurred at Lake Pocotopaug in Connecticut in 2000, during the early stages of a treatment with a similarly overbuffered mix of alum and aluminate. Fish bioassays documented that the impact was from elevated aluminum and high pH. Altering the treatment protocols with regard to alum:aluminate ratio and maximum aluminum dose to any location on any day resulted in no fish mortality in the lake during completion of the treatment in 2001. Fish kills have become a rare occurrence, however, as dose adjustments and buffering of treatments in low alkalinity lakes have become standard. It is possible to perform treatments on low alkalinity lakes without inducing aluminum toxicity, but there is still a risk.

The precipitation of the floc may also carry many other organisms, such as algae and small zooplankton, to the bottom. Changes in the algal community are expected. However, no studies indicate any major shift in zooplankton immediately following treatment. Data for zooplankton in several Maine lakes treated between 1978 and 1986 and monitored before treatment and just after treatment suggest no adverse impacts on zooplankton community composition, density or mean size. Impacts may well have occurred in the treatment zone, but refuges, resting stages, rapid reproduction and re-distribution act to minimize zooplankton impacts.

No adverse impacts on aquatic plants rooted in the sediment have been reported. With increased water clarity, growth of rooted plants at greater depths has been observed. Reduction in the density of plants that depend upon the water column for phosphorus (e.g., duckweed and watermeal) is possible.

Cost Effectiveness

The cost of phosphorus inactivation is dependent on the inactivator chosen, the needed dose, and distance from suppliers, plus the environmental constraints placed on the application, including dose limitations, application timing, monitoring and contingencies. Application costs have ranged from $1,000 to $10,000 per acre, with the more costly applications linked to precautions relating to sensitive species. For Lake Auburn, a cost of not less than $3,000 and not more than $6,000 per acre is expected. The exact area to be treated is not known, but could be between 25% and 33% of the lake area, suggesting a cost range of $1.7 million to $4.4 million. The range would be greatly narrowed by a proper planning effort.

Summary of Alternatives

This analysis shows that algicide is the only feasible and viable short-term measure for controlling algal blooms and preventing AWD/LWD from exceeding the turbidity criteria for its filtration waiver. Each of these alternatives and their impact to water quality, impact to non-target organisms, cost effectiveness, and ability to achieve a reduction in turbidity are assessed in Table 3. Watershed controls, hypolimnetic oxygenation, and phosphorus inactivation are all feasible and would likely have a significant impact on algal populations and turbidity, but these options are not viable for short-term control of a potential algae bloom in 2013. Watershed controls will likely take many years for the effect on Lake Auburn water quality to be manifest, and hypolimnetic oxygenation and phosphorus inactivation both require more study and planning before they can be implemented. Although restorative and likely effective, dredging is cost prohibitive.

Table 3. Summary of Alternatives Analysis

Alternative	Impact on Water Quality	Impact on Non-Target Organisms	Cost Effectiveness	Could Action Achieve Reduction in Turbidity?
No Action	♦ Under correct conditions it is possible, and even likely, that an algal bloom and high turbidity could occur again.	♦ If an algal bloom occurs resulting in basin-wide anoxia, the cold water fishery will again be threatened and another fish kill may occur.	♦ Low cost as no action is taken. ♦ If the filtration waiver is voided due to high turbidity, an expensive upgrade to the water treatment plant would be required.	♦ No, there is a risk that poor water quality could occur again in 2013 or beyond.
Additional Watershed Controls	♦ Will not have an immediate effect. ♦ Over time should yield a substantial increase in overall water quality. ♦ Will enhance the efficacy of in-lake management options.	♦ Should only have a beneficial impact.	♦ Vary in cost from low cost regulatory controls to high cost structural stormwater controls. ♦ Initial cost estimate is $2 million ♦ May reduce the need for short-term lake mitigation techniques in the future.	♦ Yes, but it may take many years for the effect to be realized in Lake Auburn.

Phosphorus Inactivation	♦ Possibility of long-term control of phosphorus released from sediments. ♦ Some phosphorus may be removed from the water column, but Lake Auburn phosphorus concentrations are too low for phosphorus inactivation to have a significant impact on immediate water column phosphorus.	♦ Can be toxic to fish and invertebrates. ♦ Most applications today have no adverse effects; fish kills early in the use of phosphorus inactivation resulted from improper buffering. ♦ Small organisms may be carried to the bottom, but data show that no significant impacts to populations are expected. ♦ No adverse impacts on rooted plants have been observed.	♦ Vary based on the chemical chosen, the needed dose, and environmental constraints due to sensitive species. ♦ Cost for Lake Auburn likely between \$3,000 and \$6,000 per acre. ♦ Total cost range likely between \$1.7 million and \$4.4 million.	♦ Likely yes, but more study needed to assess necessary dose, application area, and expected duration of benefits.

Hypolimnetic Oxygenation	♦ Can make a marked improvement in lake conditions, but effects are not uniform or consistent within and among aquatic systems. ♦ System must be kept running year after year. ♦ Successfully applied in New England reservoirs. ♦ Major developments in successful use of pure oxygen systems in the last decade.	♦ Very few negative impacts, and increased oxygen levels are expected to promote aquatic life. ♦ System failure after establishing an oxic zone may cause a fish kill if anoxia occurs. ♦ Oxygen or nitrogen supersaturation could cause gas bubble disease, but formation of the right size bubbles from oxygenation is not expected.	♦ Oxygen demand appears to be at the low end of the range where oxygenation is applied. ♦ Expected capital cost is between \$800 - \$2,000 per acre. ♦ Approximately half the lake could require oxygenation, representing a total capital cost of \$1.0 million to \$2.3 million. ♦ Operational costs anticipated to be on the order of \$600 to \$1,200 per day, or \$36,000 to \$72,000 per year under the current conditions.	♦ Yes, but more study is needed to determine amount of oxygen needed, area to be oxygenated, and relation between deep water quality and algal blooms.

Dredging	♦ Net positive impact for both deep and shallow alternatives. ♦ Deep alternative would remove nutrient reserves from sediment, reducing anoxic phosphorus release rate. ♦ Shallow alternative would significantly reduce or eliminate *Gloeotrichia* cysts, reducing or eliminating peak concentration during the next growing season.	♦ Impacts to biota, especially invertebrates, is likely. ♦ May increase and improve spawning habitat for many fish species. ♦ May remove pollutant reserves from sediment, improving overall aquatic habitat quality.	♦ Deep dredging (9 to 15 m) for sediment phosphorus removal will likely cost about $64 million. ♦ Shallow dredging (3 to 4.6 m) for *Gloeotrichia* removal will likely cost about $118 million.	♦ Yes, but cost prohibitive.
Algicide	♦ If applied at the right time, could kill algae before presenting a turbidity or oxygen demand issue. ♦ Short-term means of lowering turbidity until nutrient sources can be controlled.	♦ Toxicity to fish, zooplankton, and benthic invertebrates possible, but unlikely at the target dose. ♦ Primary risk is to zooplankton in the treatment area. ♦ With up to half of the lake treated, ample refuges are provided.	♦ Costs between $25 and $100 per acre; cost should not exceed $160,000 in 2013.	♦ Yes, but not a long-term solution.

References

CDM Smith (2013). *Diagnostic Study of Lake Auburn and its Watershed: Phase I*. Prepared for the Lake Auburn Watershed Protection Commission.

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Maine Department of Inland Fisheries and Wildlife [MEDIFW] (2013). Maine Endangered Species Program/Endangered and Threatened Species.
http://www.maine.gov/ifw/wildlife/species/endangered_species/species.htm

Section 5: Application Protocol

5.1 Closing of Intake

The Auburn Water District and the Lewiston Water Division have adequate storage within their distribution systems and reservoirs to supply water to the cities for at least 24 hours without withdrawing water from Lake Auburn.

In addition to maintaining a buffer zone of algaecide application around the intake structure as outlined in Figure 3 of the PDMP, no water will be withdrawn from the Lake during the algaecide application.

Water will not be taken from the lake until it is cleared by test results.

Samples will be taken by AWD/LWD laboratory staff prior to and after algaecide application at the intake. Samples will be analyzed at the AWD/LWD laboratory. Water will be withdrawn from the Lake when test results indicate that copper levels are below 0.1mg/l.

5.2 Monitoring Private Intakes

There are private homes on the Lake that withdraw water directly from the Lake. These homes will be identified through direct correspondence. Occupants will be notified in-person prior to the algaecide application taking place. They will be encourages to cease, or at least limit their use of water during the algaecide application period. Bottled water will be provided to these homes for drinking until such time as test results indicate there is no threat. Testing protocol will be similar to what is conducted around the intake as explained above in 5.1.

5.3 Boat Access

There is one public boat launch on Lake Auburn located near the outlet on Rt. 4 (refer to Topographic Map Tab B). The launch will be closed during the algaecide application. There is an entrance gate that will be locked and manned by AWD/LWD staff during the application.

In addition to the boat launch, access to the Lake can be gained by hand launching small boats; the two most notable areas include the inlet at North Auburn, and along Lake Shore Drive. Signs will be posted at these locations that indicate the Lake is closed to boats. These areas will be monitored by AWD/LWD Staff during the algaecide application. The signs will be removed at the conclusion of the application.

5.4 Direct Water Withdrawals

AWD/LWD requires that all companies (tank trucks) who withdraw water from the Lake be permitted. AWD/LWD maintains a data base of all companies who are permitted. They will be contacted immediately prior to the application to inform them that the Lake will be closed for water withdrawals until the algaecide application has been completed and test results indicate the Lake has been cleared.

5.5 Water Patrol

During the algaecide application, AWD/LWD will deploy three boats to monitor the activities.

- Lab Manager - One boat will be used by the Lab Manger to collect samples for lab analysis.
- Hazmat Team – AWD/LWD maintain an internal Hazmat team that is trained to respond to emergencies. Members of the hazmat team will be on the water, and be available to respond to emergencies. The team maintains a trailer that is equipped with booms, absorbent pads, decontamination equipment, etc. This trailer will be parked at the boat launch and ready to go if needed.

5.6 Agency Notification

The following Agencies will be notified in advance of the algaecide application

- Maine Warden Service
- Maine Department of Inland Fisheries and Wildlife
- Health Officers for Auburn and Lewiston
- Maine Drinking Water Program
- Maine State Police
- Maine Department of Environmental Protection
- 911
- Auburn Police Department
- Auburn/Lewiston City Buildings

In addition, personnel from the Auburn Water District, and Lewiston Water Division will be manning the phones at the regular business offices at the time of algaecide application to answer any questions or concerns from the public.

5.7 Police Patrol

As part of their operating budget, The Lake Auburn Watershed Protection Commission (LAWPC) hires the Auburn Police Department (APD) to perform routine patrols of the watershed. During the algaecide application, APD will be hired to be present and monitor activities around the Lake.

5.8 Incident Command System

Given the multiple agency coordination that will be required , AWD/LWD will be managing the algaecide application project utilizing the Incident Command System as defined in the National Incident Management System (NIMS).

This project will use an ICS trained management team to develop written plans and procedures, will conduct daily briefings and debriefings, will conduct an After Action Review and develop a lessons learned report that may be shared with interested agencies that are involved in this type of project.

Life Safety Specialists (PO Box 6 • Norway, Maine 04268-0006 • Telephone: 207-744-0135) will be procured to work as a facilitator for the management team on the project and to provide the NIMS implementation service.

SECTION 6: Response Procedures

6.1 Spill Response Procedures

The spill response procedures will be handled by Aquatic Control Technologies, the company hired by the LAWPC to conduct the pesticide application.

The spill response procedures are presented below. A copy of Aquatic Control Technologies' Standard Operating Procedure (SOP) for Chemical Spill Events is contained in Attachment A.

The employees from Aquatic Control Technologies assigned to the pesticide application of Lake Auburn are familiar with the material being used. They are familiar with the risks of exposure and the required first aid procedures. Likewise, they will have the necessary absorptive material (i.e., kitty litter, clay, activated charcoal or sawdust), hydrated lime and soap/detergent in the vehicle traveling to the treatment site.

In the event of a spill, the following protocol will be followed.

<u>Assess the situation:</u> The following will be considered: Is there a fire, spill or leak? What are the weather conditions? What is the terrain like? Who/what is at risk? What resources are required and are they readily available?

<u>Notifications</u>: If the leak, spill, or other release into the water contains a hazardous substance or oil in an amount equal to or in excess of a reportable quantity occurs in any 24-hour period, an employee of the Water Treatment Plant will notify the National Response Center immediately at **(800) 424-8802**.

<u>Contact Emergency Response</u>: The emergency response number for **MaineDEP (800) 482-0777 (Emergency Hotline)** will be called. Help will be obtained if needed. If the spill is very large or of highly toxic material then **ChemTrec at 1-800-424-9300** will be contacted. The Water Treatment Plant's Superintendent will be notified as well as the Town's Department of Public Health.

<u>Personal Protective Equipment</u>: All personnel aiding with the containment and clean-up of the spill will be wearing the necessary Personal Protective Equipment (PPE).

<u>Control the Spill</u>: Necessary steps to end the leakage of additional material by righting punctured drums, placing them in new, oversized containers or other means will be taken.

<u>Contain the Spill</u>: Absorbents, earthen dykes or other means will be used to limit the spread of the spilled pesticide.

<u>Clean up the Spill</u>: After the spill has been contained and liquid pesticide absorbed on a solid material or special spill control gels, the contaminated absorbent will be picked up and bagged for proper disposal. The area must be further decontaminated through use of soapy water or with some pesticides alkaline material such as lye.

<u>Report the Spill</u>: All necessary authorities and interested parties will be notified of the spill and the efforts made to control, contain and clean up the spill.

Document the Spill: Documentation of the spill will be made in accordance with the SOP in Attachment A.

6.2 Adverse Incident Response Procedures

As with the spill response procedures, the adverse incident response procedures will be handled by Aquatic Control Technologies, the company hired by the LAWPC to conduct the pesticide application. The adverse incident response procedures are presented below. A copy of Aquatic Control Technologies' Standard Operating Procedure (SOP) for Adverse Incidents is contained in Attachment A. Following an adverse incident, the following will be done.

Investigate the Site and Assess the Situation Immediately:
Answers to the following questions will be documented:

- What has occurred?
- What pesticides have been applied and could they have contributed to the incident?
- Who/what else may still be at risk?
- What are the weather conditions?
- What is the terrain like?
- Can anything be done to mitigate further damage (example aeration)?
- What resources are required and are they readily available?

Report Immediately:
The following notifications will be made:

- The Maine Board of Pesticide Control (207-287-2731)
- The Maine Department of Environmental Protection (207-822-6300)
- The Maine Department of Inland Fisheries and Wildlife (207-287-8000)
- The EPA Region 1 (617-918-1579)

As well as any other department responsible for receiving reports of adverse incidents in Maine will be contacted, and assistance will be requested if necessary. Also incident will be reported to the LAWPC, AWD, LWD, and other interested parties. The incident notification will be performed in accordance with the SOP.

Collect Water and Soil Samples:
Samples will be collected in opaque glass jars and the samples will be frozen. The samples will be shipped overnight on ice to a designated laboratory for analysis of pesticide content as soon as possible.

Collect Dead Animal/ Fish Samples:
If the adverse incident is a wildlife and/or fish kill, samples of the dead animals/fish will be collected. The specimens will be wrapped in aluminum foil or placed inside a glass jar and frozen (for preservation purposes). Pesticide testing of the samples may be requested.

Adverse Incident Reporting:
An Adverse Incident Report will be prepared in accordance with the SOP. Additionally, a report will be prepared and filed with the PDMP, as detailed in Attachment A.

SECTION 7: Signature Requirements

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the application of pesticides, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Name: SID HAZELTON P.E. Title: DISTRICT ENGINEER AWSD
Signature: Sid Hazelton Date: 4/2/13

SECTION 8: PDMP Plan Modifications

The PDMP will be modified if there is a change in the type and/or quantity of the pesticide application. Changes to the PDMP will be made prior to the next pesticide application, if practicable or if not, no later than 90 days after any changes to the pesticide application activities. Changes in personnel, updates to the site maps and so on will be included in a revised PDMP. The revised PDMP will be signed and dated in accordance with the Pesticide General Permit (PGP) requirements.

SECTION 9: PDMP Availability

- A copy of the current PDMP, along with all supporting maps and documents, at the address provided in Section III.3 of the NOI will be retained. The PDMP and all supporting documents will be readily available, upon request, and copies of any of these documents provided, upon request, to EPA; a State, Territorial, Tribal, or local agency governing discharges or pesticide applications within their respective jurisdictions; and representatives of the U.S. Fish and Wildlife Service (USFWS) or the National Marine Fisheries Service (NMFS). EPA may provide copies of your PDMP or other information related to this permit that is in its possession to members of the public.
- Any Confidential Business Information (CBI), as defined in 40 CFR Part 2, may be withheld from the public provided that a claim of confidentiality is properly asserted and documented in accordance with 40 CFR Part 2; however, CBI must be submitted to EPA, if requested, and may not be withheld from those staff within EPA, FWS, and NMFS cleared for CBI review.

ATTACHMENTS

Attachment A – Response Procedures Document(s)/ Adverse Incident Report(s)

Standard Operating Procedures for:

Chemical Applications
Chemical Spill Events
Adverse Incidents
Post Treatment Monitoring

Standard Operating Procedure
For Chemical Applications

Prior to leaving the office:

- ☐ Ensure proper notifications have been made
- ☐ Read all applicable permits and address any requirements necessary for compliance; bring copies of permits
- ☐ Read label instructions; bring copies of specimen labels
- ☐ Check equipment maintenance log to ensure all equipment has been recently calibrated
- ☐ Check that the necessary Personal Protection Equipment (PPE), Personal Floatation Devices (PFD), permits and regionally compliant posters have been placed in the vehicle traveling to the site
- ☐ Check that all necessary fuel, pesticides and equipment are properly secured within the vehicle

Upon Arrival at Site:

- ☐ Check boat and trailer and remove any plant fragments
- ☐ Post notification posters in accordance with regional regulations:
    - o Posters must be placed every 200 feet and at all public access points
- ☐ Verify the treatment area location; use GPS to verify where applicable.
- ☐ Verify the target species presence and growth stage
- ☐ Bring necessary PPE and PFD

Treatment:

- ☐ Fill spray tank half-way with lake water
- ☐ Test the spray equipment with water first. Check for any leaks or other possible equipment malfunctions. Verify equipment calibration.
- ☐ Add concentrated herbicide to spray tank, containing lake water
- ☐ Triple rinse all empty herbicide containers, disposing of the rinsate into the spray tank.
- ☐ Fill spray tank the remainder of the way to the fill line with lake water.
- ☐ Mix
- ☐ Apply herbicide evenly to the treatment area in accordance with the label and in such a way so as to avoid drift
- ☐ Following completion of treatment rinse all spray equipment and boat with lake water in designated treatment areas

Prior to Departure from Site:

- ☐ Check that all fuel, pesticides, empty herbicide containers and equipment are properly secured within the vehicle
- ☐ Check boat and trailer and remove any plant fragments

Standard Operating Procedure
For Chemical Spill Events

Prior to a Spill Event:

- ☐ Read the label
- ☐ Be prepared for emergency exposures and know the first aid procedures
- ☐ Ensure that absorptive material (kitty litter, clay, activated charcoal or sawdust), hydrated lime and soap/detergent are in the vehicle traveling to the treatment site.

Following a Spill Event:

- ☐ Assess the situation Consider the following: is there a fire, spill or leak? What are the weather conditions? What is the terrain like? Who/what is at risk? What resources are required and are they readily available?
- ☐ Contact Emergency Response: Contact the emergency response number for the state in which spill occurred (see back) and obtain help, if needed. If spill is very large or of highly toxic material or a material that you are unfamiliar with contact ChemTrec at
  1-800-424-9300
- ☐ Personal Protective Equipment: Ensure all personnel aiding with the containment and clean up of the spill are wearing the necessary Personal Protective Equipment
- ☐ Control the Spill: Take steps to end the leakage of additional material by righting punctured drums, placing them in new, oversized containers or other means
- ☐ Contain the Spill: Use absorbents, earthen dykes or other means to limit the spread of the spilled pesticide.
- ☐ Clean up the Spill: After the spill has been contained and liquid pesticide absorbed on a solid material or special spill control gels, the contaminated absorbent must be picked up and bagged for proper disposal. The area must be further decontaminated through use of soapy water or with some pesticides alkaline material such as lye.
- ☐ Report the Spill: Ensure that all necessary authorities and interested parties have been notified of the spill and the efforts made to control, contain and clean up the spill. **ME DEP** Emergency Hotline **(800)482-0777.**

Standard Operating Procedure
For Adverse Incident

Following an Adverse Incident:

- ☐ Investigate the Site and Assess the Situation Immediately: Consider the following: What has occurred? What pesticides have been applied and could they have contributed to the incident? Who/what else may still be at risk? What are the weather conditions? What is the terrain like? Can anything be done to mitigate further damage (example aeration)? What resources are required and are they readily available?

- ☐ Report Immediately: Contact the Maine Department of Environmenal Protection (207-822-6300) Maine Board of Pesticide Control (207-287-2731, the Maine Department of Inland Fisheries and Wildlife (207-287-8000) and the EPA Region 1 (617-918-1579) as well as any other department responsible for receiving reports of adverse incidents in the State of Maine. Report the incident and obtain help, if needed. Also report incident to property owners and other interested parties

- ☐ Collect Water and Soil Samples: Collect samples in opaque glass jars and freeze the samples. Send overnight on ice to lab for analysis of pesticide content as soon as possible.

- ☐ Collect Dead Animal Samples: If the adverse incident is a wildlife kill, collect samples of the dead animals, wrap them in aluminum foil or place them in a glass jar and freeze them. These samples may be requested for pesticide testing.

Standard Operating Procedure
For Post-Treatment Monitoring

Prior to leaving the office:

- ☐ Ensure proper notifications have been made
- ☐ Check that copies of permits, maps of the treatment areas and records of pre-treatment conditions are in the vehicle going to the site
- ☐ Check that all necessary fuel and equipment are properly secured within the vehicle

Upon Arrival at Site:

- ☐ Check boat and trailer and remove any plant fragments
- ☐ Bring PFD's and required monitoring equipment

Monitoring:

- ☐ Locate the treatment areas using the provided treatment maps
- ☐ Take field measurements of water clarity, temperature and dissolved oxygen, if applicable
- ☐ For each treatment area take note of both the overall percent bottom cover and target species percent bottom cover separately using the following index: 0 = no plants; 1 = 1-25% cover; 2 = 25-50% cover; 3 = 50-75 % cover; 4 = 75-100% cover
- ☐ For each treatment area take note of both the overall bio-volume of the vegetation and the target plant species bio-volume separately using the following index: 0=no plants; 1 = 1-25% bio-volume; 2 = 25-50% bio-volume; 3 = 50-75 % bio-volume; 4 = 75-100% bio-volume
- ☐ Take note of impacts to non-target species, if any.

Prior to Departure from Site:

- ☐ Check that all fuel and equipment are properly secured within the vehicle
- ☐ Check boat and trailer and remove any plant fragments

Attachment B – Corrective Action Log

Project Name:
PDMP Contact:

Date	Description of Problem Triggering the Corrective Action	Corrective Action Needed (including planned date/responsible person)	Date Action Taken/Responsible Person

Attachment C – PDMP Amendment Log

Project Name:
PDMP Contact:

Amendment No.	Description of the Amendment	Date of Amendment	Amendment Prepared by [Name(s) and Title]

Attachment D – Subcontractor Certifications/Agreements

SUBCONTRACTOR CERTIFICATION
PESTICIDE DISCHARGE MANAGEMENT PLAN

Project Number: ______________________________

Project Name: ______________________________

Decision-maker(s): ______________________________

As a subcontractor, you are required to comply with the Pesticide Discharge Management Plan (PDMP) for any work that you perform for the above designated project. Any person or group who violates any condition of the PDMP may be subject to substantial penalties or loss of contract. You are encouraged to advise each of your employees working on this project of the requirements of the PDMP. A copy of the PDMP is available for your review.

Each subcontractor engaged in pesticide activities in the pest management area that could impact Waters of the United States must be identified and sign the following certification statement:

I certify under the penalty of law that I have read and understand the terms and conditions of the PDMP for the above designated project.

This certification is hereby signed in reference to the above named project:

Company: ______________________________

Address: ______________________________

Telephone Number: ______________________________

Type of pesticide application service to be provided: ______________________________

____

____

Signature: ______________________________

Title: ______________________________

Date: ______________________________

Attachment E – Delegation of Authority

Delegation of Authority

I, ______________________ (name), hereby designate the person or specifically described position below to be a duly authorized representative for the purpose of overseeing compliance with environmental requirements, including the Pesticide General Permit, for the ____________________________________ project. The designee is authorized to sign any reports, other documents required by the permit.

____ (name of person or position)
____ (company)
____ (address)
____ (city, state, zip)
____ (phone)

By signing this authorization, I confirm that I meet the requirements to make such a designation as set forth in Appendix B, Subsection B.11.A of EPA's Pesticide General Permit (PGP), and that the designee above meets the definition of a "duly authorized representative" as set forth in Appendix B, Subsection B.11.A.

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the pest management area, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Name: ____

Company: ____

Title:____

Signature:____

Date:____

Attachment F – Annual Reports and Other Record Keeping

The following is a list of records that will be kept at our site and available for inspectors to review:

– Copies of Annual Reports

– Records as required in PGP Part 7.4

NOTES:

Note: An "Operator" is defined as any entity associated with the application of pesticides that results in a discharge to Waters of the United States that meets either of the following two criteria: (1) any entity who performs the application of a pesticide or who has day-to-day control of the application (i.e., they are authorized to direct workers to carry out those activities); or (2) any entity with control over the decision to perform pesticide applications including the ability to modify those decisions. Operators identified in (1) above are referred to in the permit as Applicators while Operators identified in (2) are referred to in the permit as Decision-makers. As defined, more than one Operator may be responsible for complying with this permit for any single discharge from the application of pesticides.

A "Pest Management Area" is defined as the area of land, including any water, for which an Operator has responsibility for and is authorized to conduct pest management activities as covered by the PGP permit. The Pest Management Area could include contiguous and non-continuous sites.